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U.S. Dept. of Army

WAR DEPARTMENT

TECHNICAL MANUAL

INSTRUCTION GUIDE

SOUND LOCATOR M2

October 11, 1940



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1940



WAR DEPARTMENT,
WASHINGTON, October 11, 1940.

TM 9-2660, Instruction Guide, sound locator M2, contains a detailed description of the operation and theory of the sound locator M2. It is intended for training of personnel of the Ordnance Department and of the using arms, in cases where it is desired that they have such background information as is not provided by the operating instructions given in TM 9-360, 3-inch AA gun matériel.

This manual was prepared by the Sperry Gyroscope Company, Incorporated, for the use of the War Department. It is a revision of part I of the handbook of the sound locator M2, which will not be republished.

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BY ORDER OF THE SECRETARY OF WAR:

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(For explanation of symbols see FM 21-6.)

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FOREWORD

1. A sound locator of the M2 series is an instrument for determining the angular position of an aerial target by the sound it emits. It accentuates and utilizes the ability of an observer to determine the direction of a sound source by means of the binaural sense. The apparent direction of the sound source, corrected for sound lag and other effects, is continuously transmitted in terms of corrected azimuth and elevation to the searchlight.

2. This sound locator receives sound by means of three horns. From these horns the sound is conducted by acoustic tubing to two listeners, one of whom controls the azimuth direction of the instrument by means of a handwheel, while the other controls the elevation by a second handwheel. A third operator inserts corrections in the data for sound lag and other effects before transmission to the searchlight. The weight of the sound locator is approximately 500 pounds without its cable and cable reels, carrying case, covers, and spare parts. It can be placed in position by three men, and can be transported with all its accessories on the truck which carries the associated searchlight.

3. For best results with the sound locator, it is recommended that operators be provided whose hearing meets the standard of section VI. They do not need to know the theory underlying the sound locator in order to operate it, but a general knowledge of its principles and construction will prove valuable in learning how to supervise its operation, how to service it, and what to expect of it. For this reason section II is devoted to an explanation of the principles on which the sound locator works, explaining the errors inherent in this method of locating a target and the corrections made for them. Other sections give detailed directions for the operation of the equipment and instructions for its routine care and maintenance.

CONTENTS

	Page
AUTHORIZATION PAGE.....	I
FOREWORD.....	II
TABLE OF CONTENTS.....	III
LIST OF ILLUSTRATIONS.....	V
GLOSSARY.....	VI
SECTION I. Introduction.....	1
SECTION II. Principles of operation	
I. General.....	2
II. Sound lag error.....	4
III. Wind error.....	8
IV. Parallax error.....	9
SECTION III. Description of mechanism	
I. General.....	13
II. Acoustical system.....	14
A. Horns.....	14
B. Sound conducting tubing.....	15
C. Helmets.....	15
III. Corrector assembly.....	16
A. Main case assembly.....	16
Stationary assembly (base).....	16
Revolving assembly (housing).....	17
B. Pantograph drive assembly.....	19
Speed corrector assembly.....	19
Parallax offset mechanism.....	20
C. Corrector drive assembly.....	20
IV. Data transmission system.....	22
A. Data transmitters.....	22
B. Spring brush and terminal block assemblies.....	23
C. Cut-out switch.....	23
D. Cables.....	23
V. Platform and column.....	24
VI. Characteristics.....	24
SECTION IV. Operation	
I. Assembling the sound locator.....	25
II. Orienting and synchronizing in azimuth.....	27
A. The searchlight.....	28
B. The sound locator.....	29
C. The control station.....	31
III. Orienting and synchronizing in elevation.....	31
A. The searchlight.....	31
B. The sound locator.....	31
C. The control station.....	31
IV. Preparing to track a target.....	31
V. Tracking a target.....	33

INSTRUCTION GUIDE

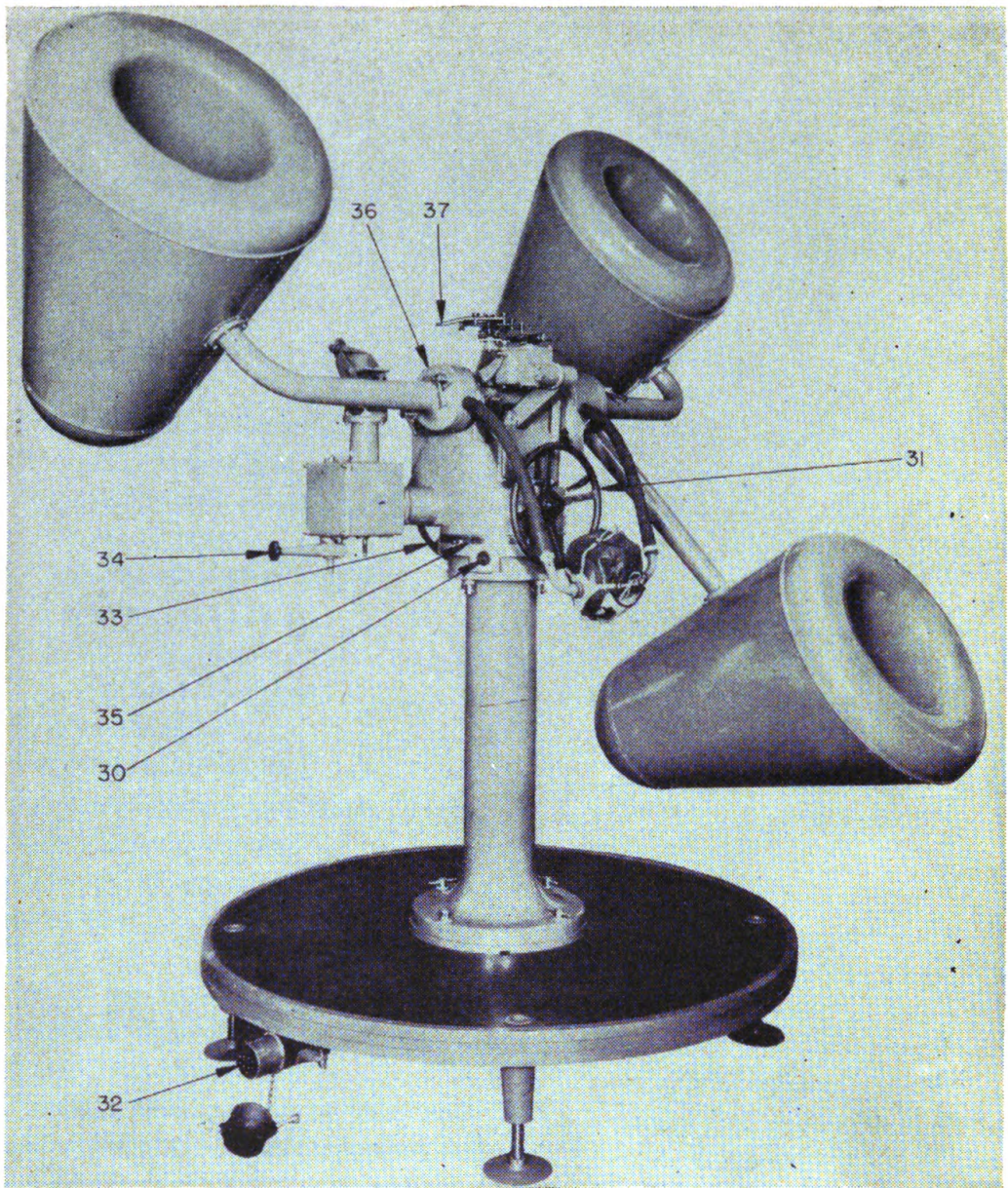
SECTION V. Routine maintenance	Page
I. General.....	34
II. Transportation.....	34
III. Cleaning.....	35
IV. Check tests.....	37
A. Course indicator.....	37
B. Parallax pointer.....	37
C. Pantograph and sight mirror.....	37
D. Over-all tests (problems).....	38
V. Lubrication.....	38
VI. Accessories.....	40
SECTION VI. Training of personnel	
I. General.....	41
II. Choosing operators.....	42
III. Elimination examinations.....	42
IV. Field training.....	43
APPENDIX A. References.....	44
APPENDIX B. Computation of corrections	
I. General.....	45
II. Sound lag correction.....	45
III. Parallax correction.....	50
IV. Combined sound lag and parallax correction.....	52
APPENDIX C. Inspection report—Sound locator M2.....	59

LIST OF ILLUSTRATIONS

Figure	Title	Page
Frontispiece	The Sperry sound locator and corrector.	
1	Sound lag principle.....	4
2	Corrector principle.....	5
3	Ball analyzer principle.....	7
4	Application of ball analyzer principle.....	7
5	Action of ball analyzer.....	7
6	Wind effect principle.....	9
7	Parallax principle.....	10
8	Cross section of horn assembly.....	14
9	Pantograph drive assembly.....	18
10	Placing corrector assembly on column.....	26
11	Attaching azimuth horn to corrector assembly.....	27
12	Attaching elevation and common horn unit to corrector assembly.....	28
13	The corrector operator in action.....	29
14	Tracking a target.....	30
15	Listener's helmet.....	32
16	Stowage box for corrector assembly.....	35
17	Corrector assembly in stowage box.....	36
18	Front view—corrector assembly.....	39
19	Cross section of main case.....	40
20	Sound lag problem (horizontal view).....	47
21	Sound lag problem (elevation view).....	47
22	Sound lag problem (elevation view).....	48
23	Parallax correction angle principle.....	51
24	Typical parallax problem.....	51
25	Sound lag and parallax combined.....	52
26	Altitude determination principle.....	54
27	Slant range determination principle.....	54
28	Slant plane (horizontal projection).....	55
29	Actual slant range determination.....	55
30	Graph of parallax settings.....	56
31	Schematic gearing diagram.....	63
32	Schematic wiring diagram.....	64

GLOSSARY

Apparent azimuth angle.....	A'
True azimuth angle.....	A_0
Apparent slant range.....	D
True slant range.....	(D_0)
Apparent elevation angle.....	E'
True elevation angle.....	E_0
Height of target.....	H
True horizontal range.....	R
Target air speed.....	S_a
Target ground speed.....	S_g
Apparent target position.....	T
True target position.....	T_0
Velocity of sound.....	V_s
Base line.....	b
Time.....	t
Sound lag time.....	t_s
Angle of approach.....	α
Angle between b and R	β
Parallax azimuth correction to height.....	(σ_2)
Azimuth correction for sound lag.....	σ_z
Azimuth angle tracking rate.....	Σ_a
Elevation angle tracking rate.....	Σ_e
Parallax elevation correction to height.....	σ_2
Elevation correction for sound lag.....	σ_z
Subscripts h indicate horizontal projections of space points.	
Subscripts 0 indicate points of true target position.	
Absent subscripts indicate points of apparent target position.	
Primes indicate translation of points parallel to base line.	



FRONTISPIECE.—THE SPERRY SOUND LOCATOR AND CORRECTOR.

- 30. Portable lamp receptacle.
- 31. Azimuth handwheel.
- 32. Cable plug (female).
- 33. Elevation handwheel.

- 34. Sight crank handle and knob.
- 35. Azimuth scale.
- 36. Elevation scale.
- 37. Pantograph.

SECTION I

INTRODUCTION

1. The problem of detecting the approach of an enemy aircraft at night, and the determination of its position in space, has engaged the attention of military experts of all nations since the first use of aircraft as a military weapon.

2. Many methods have been tried, but results obtained to date show that detection by means of sound radiated from the airplane is the only method which permits the use of simple and practical field equipment. Of the various devices developed in the past to utilize sound for the purpose of detection, the horn collector with its acoustic track extended directly to the listener's ear has proven best qualified. It is ordinarily used in combination with a searchlight which it controls, and in this book such use is assumed.

3. When sound is utilized to determine the direction of an unseen aircraft in space, the direction so determined is an apparent one and not an actual one. If sound traveled with the speed of light, the Sound Locator would point to the actual position of the target. This should be analogous to seeing the aircraft, or to line-of-sight observation. In comparison with the speed of light, however, sound travels at a slow rate. This disparity of speeds gives rise to a considerable error between the indicated direction of the sound source and the actual direction of the aircraft or target. This is so especially since the speed of the target may be as high as 400 miles per hour. This error is known as sound lag, and is compensated for in the sound locator by a corrector mechanism.

4. The usefulness of a sound locator depends upon its range and the accuracy of the data transmitted to the searchlight data receiving system. The greater the distance between the sound locator and the sound source, the less will be the intensity of the sound heard. It becomes apparent, therefore, that in order to obtain maximum listening range, all extraneous noises must be reduced to a minimum. Extraneous noises may be classified under two headings.

a. Mechanical noise, or noise inherent in the design and operation of the listening equipment.

b. Ambient noise, or noise which comes from surrounding objects, or equipment.

5. Mechanical noise can be reduced to a negligible minimum by

proper design of the sound locator. Consideration must be given to the shape and construction of the sound collectors and associated sound tracks, and to the arrangement and construction of the bearings and gears. To reduce the amount of mechanical (masking) noises it becomes necessary to eliminate—

a. Reverberation of horn structure.

b. Effect of wind blowing on horn and horn supporting structure.

c. Gear and other mechanical noises transmitted to the sound tracks.

d. All air borne noise except that in the direction of the target.

6. These requirements are met by the sound locator M2 in the following manner:

a. Reverberation of the horn structure is reduced to a minimum by constructing the horn of an impregnated cloth composition and covering all metal parts in the sound system with vibration damping material.

b. Wind effect is reduced to a minimum by eliminating all sharp corners and streamlining the horn contours.

c. The sound conducting tubes are insulated from the supporting structure and from the outside horn case, which reduces the transmission of noise from gears, bearings, wind, rain, hail, etc.

d. The horn is of the semiexponential type, with the dimensions chosen to provide a "directional" characteristic.

e. The effect of ambient noise may be reduced by proper placement of the sound locator with respect to surrounding objects. It should be positioned at a point distant from the searchlight, the searchlight power plant, highways, trees, and other objects constituting either an actual or possible noise source. In addition, it is essential that personnel operate with the absolute minimum of noise. Sound discipline must be enforced in the vicinity of the sound locator for best results.

SECTION II

PRINCIPLES OF OPERATION

I—GENERAL

1. The binaural sense is possessed by all people who can hear with both ears, and is that faculty which enables a person to determine the approximate direction of a sound source. The cerebral mechanism which determines this direction does so by comparing the times of arrival of a sound wave at the two ears. With the head turned away from the direction of the sound, one ear is closer than the other to the source of the sound and therefore receives the sound impulse sooner

SOUND LOCATOR M2

than the other. The binaural sense detects this brief time interval and the listener turns his head until the indication of time difference vanishes. When this occurs the listener will be facing toward the sound source. It follows naturally that the listener could determine the direction of a sound source more accurately if the base line between the ears could be lengthened. A simple method of accomplishing this is to provide a pair of horns, spaced some distance apart, and connected to the listener's ears by means of sound conducting tubing.

2. The sound locator M2 operates on this principle. One pair of horns is used to determine the azimuth direction and one pair to determine the elevation direction. These horns are mounted on a common frame structure so that they may be controlled as a unit, both in azimuth and in elevation. They are operated by two listeners, one for azimuth and one for elevation, by means of control handwheels. Actually, but three horns are required. They are spaced approximately 60 inches apart, as measured from horn center to horn center, and are placed at the vertices of a right triangle, one leg of which is rotated in a horizontal plane and the other leg in a vertical plane. The horn at the right angle vertex of the triangle serves a dual purpose, being used for both azimuth and elevation. The two outer horns have single sound paths, while the center horn, because of its double function, has a split sound path. This provides for conducting the sound to the elevation listener as well as to the azimuth listener. Mechanisms are provided within the sound locator to correct for errors which are inherent in this method of finding the direction of an airplane target. A more detailed description of the sound locator will be found in section III.

3. Corrections are applied for two specific errors: (1) sound lag and (2) parallax. The first error results from natural causes and the second is a result of the tactical displacement of the sound locator position from the searchlight position. A third type of error caused by wind is partly self-compensated. These errors are described in the following paragraphs.

4. When reference is made to corrections in azimuth and/or elevation, or direction in azimuth and elevation, the reference is to the movement of the horns, and not the target. As an illustration, consider a target flying in a large circle about the sound locator, at a constant altitude. The horns must then be moved continuously in azimuth but not in elevation. If the target is coming in a straight line toward and over the sound locator, the horns must be moved continuously in elevation but not in azimuth. For other target courses the horns must be moved in both azimuth and elevation. Therefore,

when reference is made to the fact that the line of sight to the target is changing in azimuth and elevation, it does not mean that the target is turning and climbing. It means that the target course is such that the horns must be moved both in azimuth and elevation to track the target.

II—SOUND LAG ERROR

5. Consider an airplane being tracked by a sound locator, and, at a certain instant, a shot is fired by the pilot. As soon as the report is heard by the listeners at the sound locator, the instrument will be directed to the point in space from which the shot was fired. But while the sound of the shot has been traveling toward the listeners,

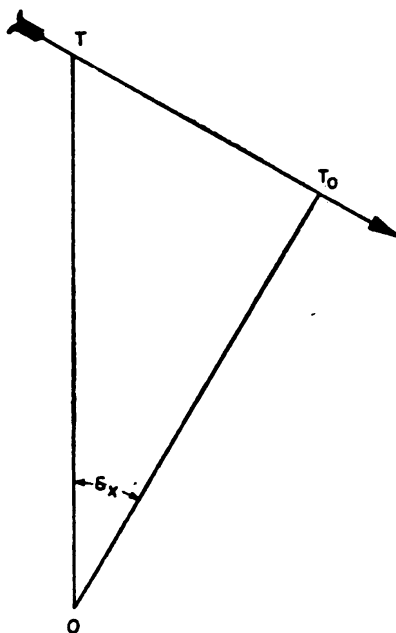


FIGURE 1.—SOUND LAG PRINCIPLE.

the airplane will have traveled a considerable distance along its course, for sound travels relatively slowly. It is apparent, therefore, that the sound locator will be pointing to a position behind the target at all times. The sound lag angle in the slant plane is caused by the time lag of the emitted sound, and the extent to which the sound locator "lags" behind the true position of the target depends upon the speed of the target.

6. Consider movement of the target at zero elevation as represented by the arrow in figure 1. When the target is at T , assume that it emits a noise which reaches the observer at O in one second. During that second, however, the target has moved at a speed of S_a feet per second for $S_a t$ feet and has reached T_0 . The speed of sound is taken

SOUND LOCATOR M2

as 1,100 feet per second, so that the line OT has a length of 1,100 feet. Therefore, the ratio of TT_0 to TO is independent of time and is dependent only upon target speed, with a numerical value of $\frac{S_a}{1,000}$. To obtain δ_x the course angle must also be known, since in general the triangle OOT_0 contains no right angles.

7. The principle of the corrector mechanism is illustrated in figure 2. Referring to the figure, CD represents the course of a target flying at constant altitude. The sound locator is at point O , and is binaurally centered in azimuth and elevation on point T , which is the apparent target position. However, point T_0 is the actual target

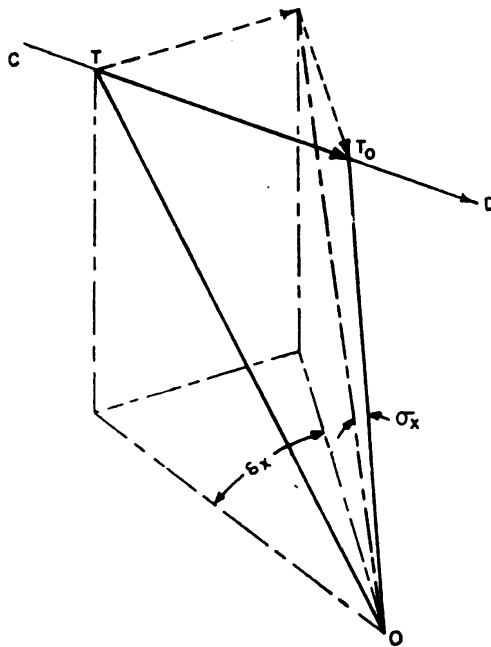


FIGURE 2.—CORRECTOR PRINCIPLE.

position when the sound emitted at point T is heard at point O . A searchlight at point O , with its beam along line OT would have to be turned in azimuth through angle δ_x , and in elevation through angle σ_x , to make its beam point in the direction OT_0 and illuminate the target. The angles δ_x and σ_x are the sound lag angles. These must be applied to the data transmission system to convert the data to line of sight observation.

8. The corrector mechanism sets up points O , T , and T_0 in miniature, to form a working scale model of figure 2. The distance TT_0 is obtained by an estimate of target speed. Sound lag angles are determined by sighting from point O to point B , in the model, figure 9. The corrector operator's line of sight, OB , if extended, would pass

through the actual target position, and in daytime practice he should be able to see the target beyond the pantograph ball, providing there is no parallax correction. As an aid to determining the accuracy of daytime practice the cross lines of the sight mirror are made so that an imaginary circle enclosing the cross lines subtends an angle of about 10° . With proper training the listener should consistently keep the target well within this circular area when the corrector operator keeps the pantograph pointer centered on the cross lines.

9. Since in the space triangle the ratio of the two legs, $\frac{TT_0}{TO}$, was shown to be equal to the ratio $\frac{S_a}{1,000}$ (see paragraph 6), we can set up a scale model in the corrector mechanism as shown in figure 9. Here AO represents TO to scale and AB represents TT_0 to scale. Assuming the speed of sound to be substantially constant in air, the leg AO is kept constant at an arbitrary value of 7.5 inches and the length of the leg AB is adjusted by an estimation of target speed so that the corrector triangle OAB is always similar to the space triangle OTT_0 . Reduced to the scale of the model, where 1,100 is represented by 7.5 inches, AB for 100 miles per hour is equal to $\frac{147}{1,100} \times 7.5 = 1$ inch, approximately. By substitution of other values of S_a , and using the same equation, it will be found that a target speed of 200 miles per hour = 2 inches, 300 miles per hour = 3 inches, and 400 miles per hour = 4 inches, all to a close approximation. In the special case where the target is at zero elevation and is moving at right angles to the heading of the sound locator, the corresponding sound lag angles are:

For 100 miles per hour (air speed) $\delta_x = \tan^{-1} 147/1100 = 7.6^\circ$
 200 miles per hour (air speed) $\delta_x = \tan^{-1} 293/1100 = 14.9^\circ$
 300 miles per hour (air speed) $\delta_x = \tan^{-1} 440/1100 = 21.8^\circ$
 400 miles per hour (air speed) $\delta_x = \tan^{-1} 588/1100 = 28.1^\circ$

10. Correction for sound lag must be made along a line parallel to the actual target course. Unless the pantograph ball is moved along the correct course line and in the proper direction in the working model of the corrector mechanism, the line OB , figure 9, if extended into space will not strike the target.

11. Therefore, there must be a determination of target course angle, with respect to the line from the apparent target position to the sound locator. This determination of course angle can then be used to move the pantograph ball so as to correct for sound lag. This course angle determination is the function of the analyzer.

SOUND LOCATOR M2

12. The practical method of obtaining a determination of target course angle is to utilize the relative azimuth and elevation motion of the horns in tracking the target, for the target course angle must be a factor entering into the resultant horn movement.

13. Figure 3 is a schematic illustration of the ball analyzer operation. It is seen that the elevation movement and azimuth movement of the horns, in tracking a target, are applied to a resolving ball through two rollers, mounted at right angles with respect to each other. For the movement of the rollers as indicated, the resolving ball will be driven toward the elevation roller and the azimuth roller, with a resultant motion in the direction F . As shown in figures 4 and 5, a small model of an airplane is mounted and pivoted at point

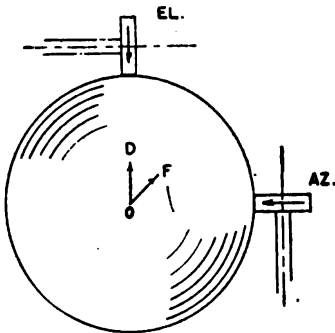


FIGURE 3.—BALL ANALYZER PRINCIPLE.

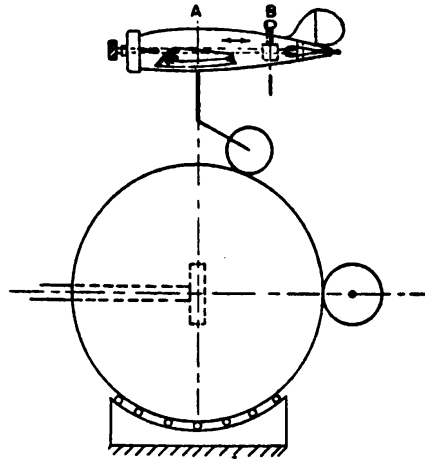


FIGURE 4.—APPLICATION OF BALL ANALYZER PRINCIPLE.

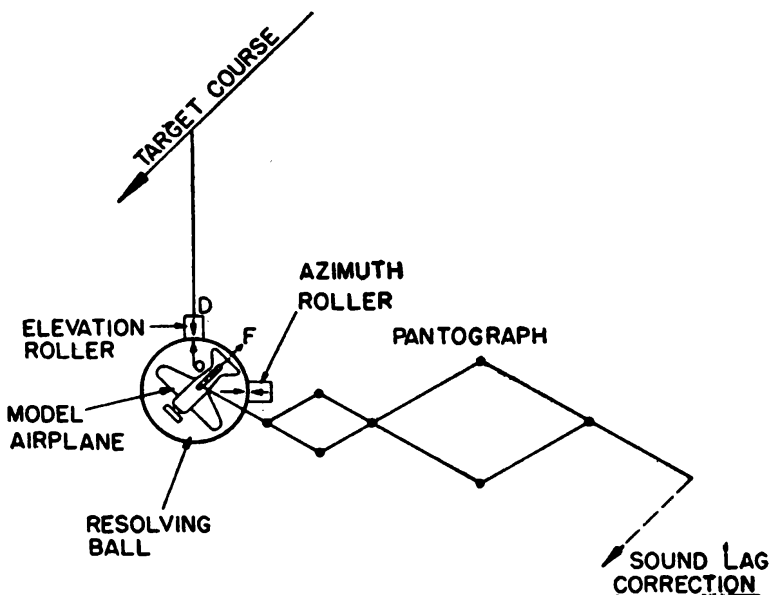


FIGURE 5.—ACTION OF BALL ANALYZER.

A, with its motion restricted to a rotation about a vertical axis at A, and carrying a caster. When the caster aligns itself with the direction of motion of the ball's surface, the model also is so aligned, and indicates resultant ball motion and the course angle of the target.

14. For the computations and equations underlying the design of the sound lag correction mechanism, see appendix B.

III—WIND ERROR

15. In the discussion so far, the speed of the target through the air has been considered to be the same as its speed over the ground. Such conditions prevail only when there is an absolute calm. The presence of wind immediately alters this problem, in that ground speed becomes greater or less than air speed, dependent upon the direction and force of the wind with respect to the target course. Wind alone acts in the same manner as the speed of the target, to cause a difference between the apparent and the true position of the target. The error caused by wind occurs simultaneously with the error caused by sound lag. Therefore, it is best to treat wind error and sound lag together.

16. Figure 6 indicates how this is accomplished in the case of head wind. With no wind, while the target travels from point T to T_0 , sound emitted at T travels to the listener at point O . But against the wind the target will, in a similar period of time, travel only as far as T_0' . In the same period the wind will have carried the sound toward the left, so that the sound emitted at T will appear to come from T' . But $T_0'T_0$, the difference in target position, equals $T'T$, the difference in the apparent position of the sound source, and $TT_0 = T'T_0'$, because the wind's effect on the target is the same as its effect on the sound waves. The speed setting of the mechanism is made according to the estimated air speed of the target and therefore the mechanism predicts T_0' as the actual target position, which is correct.

17. It is to be noted that the target speed (air speed) is constant while the ground speed varies with the force of head or tail winds. All aircraft speeds are based on air speed only, not ground speed. The target speed setting applied to the corrector mechanism is, therefore, the speed at which the airplane is designed to fly through the air. It is important constantly to bear in mind that the air speed of the target is entirely independent of wind.

18. While figure 6 shows the effect of a head wind only, similar reasoning applies to a tail wind. For other than head or tail winds, assume that the wind velocity is resolved into two components, one lying along the target course and the other at right angles to the

SOUND LOCATOR M2

target course. The component lying along the target course has no effect, as explained, while the component lying at right angles to the course has a negligibly small effect and is disregarded.

IV—PARALLAX ERROR

19. Parallax is the difference in the apparent position of the target when observed from the sound locator and from the searchlight, when the two instruments are separated. Since the units are invariably separated, the uncorrected data observed at the sound locator position is not suitable for use at the searchlight position.

20. This is because the data transmission system of the sound locator causes the searchlight beam to assume the same azimuth

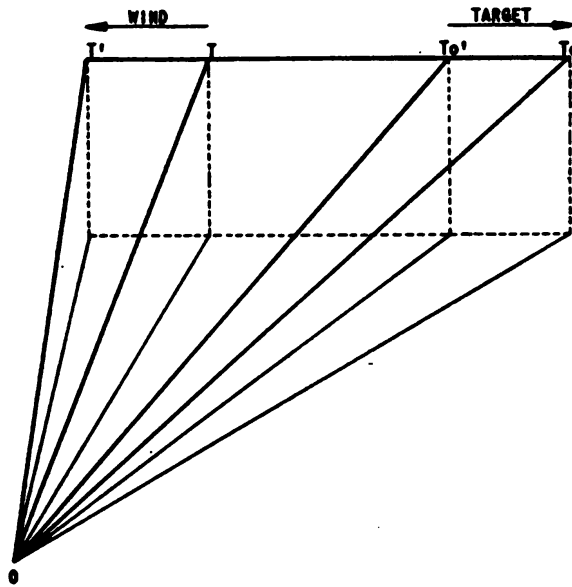


FIGURE 6.—WIND EFFECT PRINCIPLE.

angle, with respect to a common base line, as is assumed by the line between the sight mirror center and the pantograph ball. It also causes the searchlight beam to assume the same elevation angle with respect to the horizontal plane. If the two units are separated, these two lines will always be parallel in the same slant plane. Therefore, if the line from the sight mirror center to the pantograph ball were extended to strike the target, the searchlight beam would not strike the target but would strike a point at a distance from the target equal to the length of the base line. The only exception to this is in the case where the distance between the target and the searchlight is so great that the divergence, or spread, of the searchlight beam overcomes the parallelism of the two center lines.

21. This effect of parallax must be corrected. For any particular

slant range, this correction increases with the distance between the sound locator and searchlight. Since 900 feet is the maximum distance permissible with the cable supplied, the following explanation will be based on use of this distance.

22. Referring to figure 7, the sound locator is at point O and the searchlight at point L . OT_0 is the line from the sight mirror center to the pantograph ball, extended into space. The center line of the searchlight beam, LM_0 , must therefore be parallel to line OT_0 . With the target at point T_0 , the searchlight beam will not strike it. Consider now a line T_0M_0 parallel with, and equal to, the base line OL . The points T_0M_0LO now form a parallelogram in which $T_0O = LM_0$ and $T_0M_0 = OL$. This is true for any point in space, for any range, and for any base line. Furthermore, for any point in space, OT_0 and OL determine a plane and, when the slant range has been estimated,

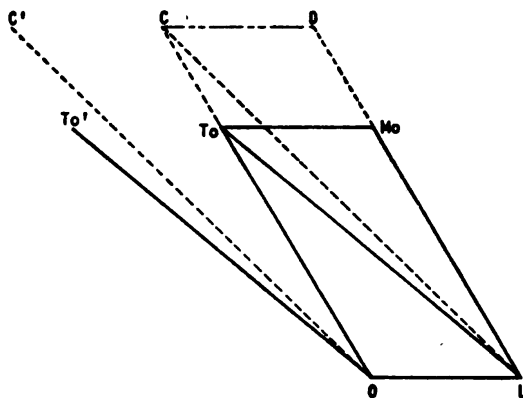


FIGURE 7.—PARALLAX PRINCIPLE.

the parallax problem is reduced to a *problem in a plane*, or in two dimensions.

23. The searchlight beam center line can, however, be made to strike the target at point T_0 by turning the searchlight through the angle M_0LT_0 , in the slant plane determined by T_0O and OL . This is equivalent to moving point M_0 to point T_0 , along the line M_0T_0 . This corrective angular motion of the searchlight beam is accomplished by moving the pantograph ball an amount proportional to the length of the base line and parallel with it. After doing this it is necessary to move the mirror through an angle equal to the angle M_0LT_0 , figure 7, in the same slant plane. This angular movement of the mirror is shown as T_0OT_0' . This motion is inserted into the data transmission system and the data transmitters will cause the searchlight to be moved through the same angle in the same slant plane. This results in the searchlight beam center line being moved from point M_0 to point T_0 .

24. In figure 7 a definite slant range has been assumed, but actually slant range may have any value within the range of the sound locator, and some method of correcting for these variations in slant range is necessary. To illustrate this variable corrective factor, assume the target to be at point C (fig. 7) instead of at point T_0 , then point M_0 will move out to point D . The lines CO and DL are then equal to and parallel with one another, as were lines T_0O and M_0L . However, as point D is moved to point C , along the line DC , the correction angle DLC is smaller than the original angle M_0LT_0 , due to the greater slant range. Therefore, the pantograph ball must be offset a proportionately smaller amount, so that correction angle $CO C'$, transmitted to the searchlight, will cause the beam to strike at point C . Referring to the parallax correction graph, figure 30, it will be seen that the pantograph ball offset distance marked on each line decreases with increasing slant range for a given base line.

25. In the corrector mechanism, the distance from the sight mirror center to the center of the pantograph ball is 7.5 inches when there is no sound lag correction. As soon as sound lag correction is inserted, this distance becomes greater or less than 7.5 inches, dependent upon the speed and course of the target. The parallax correction graph, shown in figure 30, was based on a constant distance of 7.5 inches for convenience of computation, and its use involves an estimation of the slant range, from the sound locator to the apparent target position. When the sound of the target is heard at the sound locator, the target will have advanced to a new position in space and is at some new slant range. For practical purposes, it makes little difference whether the apparent or actual slant range is estimated. The difference between the two ranges even for the worst conditions (maximum target speed and short slant range) is well within the possible error of slant range and target speed estimation. Divergence of the searchlight beam helps to offset errors in estimation of the slant range.

26. It has been established fairly conclusively that the slant range of searchlight pick-up of the target can be very closely predicted if the following factors are considered.

- a. Type of target.
- b. Whether target is camouflaged or not.
- c. Altitude of target.
- d. General conditions as to atmosphere, degree of darkness, etc.
- e. Type of searchlight to be used.

27. To a person familiar with the problem of illuminating a target at night with a standard 60-inch high intensity searchlight, the fac-

tors enumerated above can, in the majority of cases, be determined almost immediately. The type of target, whether bombing, scouting, etc., is determined by outpost listeners, it being obvious to the listeners as soon as they can hear the target. The target will usually be camouflaged in time of war, but at other times can be considered to be camouflaged if desired. The altitude of the target can be closely approximated from knowledge of the type of target, height of clouds, and information received from the outpost listeners. The atmospheric conditions, such as mist (if any), clouds, etc., are well known at all times, as is the type of searchlight being used and the degree of darkness prevailing. Among the general factors is the defense requirement that the searchlight should not be turned on until there is a good probability of picking up the target immediately, and the offense requirement that the firing time of the gun battery should not be unnecessarily curtailed.

28. The influence which these factors have on the pick-up range of the searchlight is obvious. A camouflaged target does not reflect as much light as an ordinary painted one, which will reduce the range of pick-up. A bombing plane, being larger than a scouting plane, will present a greater surface to the searchlight beam, and will therefore, be seen at a greater distance. A low flying target, at long range, will present less surface to the searchlight beam than the same target will at an equivalent range when flying high. If the night is very dark (no moon) and the atmosphere is clear it is evident that an illuminated target can be seen at a greater distance than if the moon were bright or if the night were foggy. Likewise, a 60-inch searchlight can visibly illuminate a target at a greater distance than a 36-inch searchlight can, the source of light being of the same type and intensity in each searchlight. The tactical requirements of defense and offense will in every case indicate a best range for lighting the searchlight, and this slant range, based on judgment of all factors, should be considered in making the parallax setting at the sound locator.

29. Therefore, as it is possible for a battery commander reasonably to estimate the most probable maximum range at which the target will be picked up and illuminated by the searchlight, it is advisable that the corrections for sound lag, wind and parallax be as accurately obtained as possible at such a slant range.

30. Corrections for sound lag and wind, as previously stated and explained, are obtained without the necessity of knowing the slant range. The correction for parallax, however, is solely dependent upon slant range and the length of the base line between the search-

SOUND LOCATOR M2

light and the sound locator. The base line being fixed and known, the parallax correction angle will vary according to slant range.

31. Correction for parallax is accomplished in the design by mounting the fulcrum of the pantograph on an adjustable offset pivot. The axis of this offset pivot is so mounted as to permit the direction of offset to be aligned parallel with the base line at the time of instrument orientation and, when the sound locator is rotated in azimuth, a geared connection with the azimuth handwheel preserves this alignment.

32. The amount of parallax offset of the pantograph is shown on a scale and index on the offsetting device. The scale is calibrated in arbitrary members from 0 to 10. At the zero setting there is no parallax offset, and the maximum occurs at 10. The graph shown on figure 30, which is also mounted on the side of the instrument, indicates the number to which the parallax offset should be set against the index of base lines from 200 to 1,000 feet for the various estimated slant ranges of searchlight pick-up in feet. For example, using a 900-foot base line between the sound locator and searchlight, if the estimated slant range of searchlight pick-up is 18,000 feet, the parallax offset should be 4 on the scale as shown by the intersection of the dotted line with the 900-foot base line.

SECTION III

DESCRIPTION OF MECHANISM

I—GENERAL

1. The complete sound locator M2 consists of four major assemblies, namely:

- Acoustical system
- Corrector assembly
- Data transmission system
- Platform and column

2. Structurally, the first, second and fourth assemblies are complete within themselves, while the third is a part of the Corrector Assembly. The latter is composed of three subassemblies and each will be described individually. These three are:

- A. Main case assembly
- B. Pantograph drive assembly
- C. Corrector drive assembly

3. The purpose of this section is to describe the mechanical con-

struction and operation of the sound locator. For the general explanation of the sound locator operation the reader is referred to section II, Principles of Operation.

II—ACOUSTICAL SYSTEM

4. The acoustical system consists of three subassemblies: (1) horns, (2) sound conducting tubing, and (3) listeners' helmets. Each of these items will be described individually.

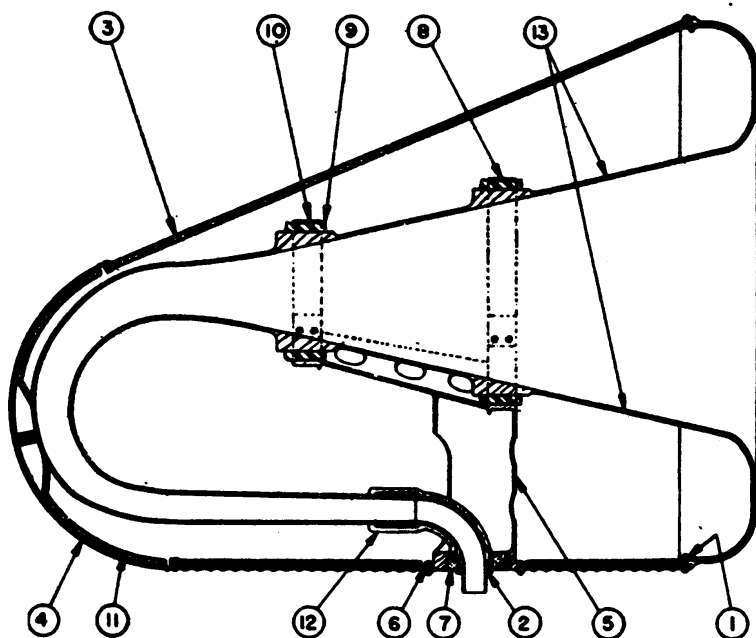


FIGURE 8.—CROSS SECTION OF HORN ASSEMBLY.

- | | |
|----------------------------------|---|
| 1. Reinforcing ring. | 9. Rubber insulation (2" wide), latex foam. |
| 2. Elbow assembly. | 10. Horn clamp strap, small. |
| 3. Body assembly (outer casing). | 11. Horn casing insulation (Seapak). |
| 4. Cap assembly, casing end. | 12. Horn elbow insulation (flame-proof felt). |
| 5. Bracket, horn support. | 13. Inner horn (impregnated cloth composition). |
| 6. Retainer ring. | |
| 7. Rubber insulation. | |
| 8. Horn clamp strap, large. | |

A. Horns

5. The horns, because of their physical design, will pick up and intensify all sounds within a 30° cone in the direction of the horn axis, i. e., 15° on either side of the center line. Sound outside this "directional" cone is amplified less and less the farther it is away from the horn's axis, until outside of a 60° cone very little ambient noise is picked up. Ground noises are, in this way, kept from the listeners' ears when the horns are elevated above 30° (533 mils).

6. The construction of the interior of the horn (see fig. 8) is

SOUND LOCATOR M2

"conical" to the throat. From the throat, the cross section of the horn decreases exponentially to the elbow assembly, 2, where the sound conducting tubing is attached.

7. The inner cone of the horn is constructed of impregnated cloth composition and the outer shell consists of aluminum, lined with corrugated sound absorbent material.

8. As shown in figure 8, the inner cone of the horn is held to an aluminum bracket by means of two aluminum straps. The cone is insulated from possible vibration of the straps and the bracket by layers of foam rubber. The bracket is, in turn, attached to the respective horn arm and thus lends itself to support of the horn proper.

B. Sound conducting tubing

9. The cross section of the tubing decreases exponentially from the elbow assembly, 2, at the horn to the listener's ears, with the exception of the short external sections called helmet tubes, extending from the clamp to the listener's ears. This exponential decrease forms an extension of the horn throat and serves to intensify the sound. The exponential tubing is of thick walled, reinforced rubber. The helmet tubes are of reinforced synthetic rubber for sound locators to be used at tropical stations, and of reinforced rubber for sound locators to be used in cold and temperate climates. The latter tubes are distinguished by a white dot molded in the rubber approximately 1½ inches from the helmet end of each tube. Where it is necessary to bend the sound path, small metal elbows, suitably covered with sound absorbent material, are used.

10. The sound collected by the vertex horn is conducted to the ears of both listeners. Because of this feature, the sound conducting tube from this horn is split at the clamp, so as to provide for this requirement.

C. Helmets

11. The listener's helmet, figure 15, is specially designed to eliminate, as much as possible, all sound other than that which is collected by the horns.

12. Metallic ear cups are built into the helmet and machined metallic bushings screw into these cups. The bushings are adjustable and may be fitted to the individual using the helmet. This provides maximum sound conduction directly to the ear canal. Aluminum elbows, which are attached to the ends of the helmet tubes, "snap fit" into the helmet bushings. This provides a quick method of operation and

eliminates the necessity of removing the helmet during non-active periods. These elbows pivot easily in the bushings, but are held firmly at all times by the snap ring. This prevents any opening of the sound path which might result in the admission of extraneous noise.

13. Although the ear cup is designated to provide an air-tight space around the ear for a variety of head shapes, the addition of a chin cup insures this tightness for any listener. Normally, with the jaw up, the listener's chin rests easily in the chin cup. By dropping the jaw, the listener causes the inner padded rims of the ear cups to be pressed as firmly as desired against the sides of the head. Thus, the padded rim can be made to conform to the contours of the head, forming an air-tight space around the ear.

14. The helmets are constructed of soft pliable leather, lined with chamois. They are provided in the two sizes, medium and large. Reference should be made to paragraph 28, section IV, for instructions relative to fitting the helmet.

III—CORRECTOR ASSEMBLY

A. Main case assembly

15. The main case assembly consists of two subassemblies: (1) the stationary assembly, or base, and (2) the revolving assembly, or housing.

Stationary assembly (base).

16. The base includes the azimuth train gear, azimuth scale, slip ring assembly, portable lamp receptacle, and the short extension cable. The base is formed of cast aluminum.

17. The azimuth train gear is mounted within the top of the base (see frontispiece) and is rigidly fastened to it. The azimuth scale, 35, fits around the outside of the base, almost flush with the top edge. This scale is graduated in mils (0-6400) and is adjustable by means of a clamp screw.

18. The slip ring assembly consists of a short hollow column, upon which the slip rings are concentrically mounted, and insulated therefrom. The column is machined for an upper and a lower bearing which, in turn, support the revolving assembly. This column is bolted vertically to the center of the base.

19. The portable lamp receptacle, 30, is mounted on the outside of the base, and is to be used only for a servicing lamp in the field. DO NOT operate power tools from this receptacle.

20. The short extension cable terminates at one end on a terminal block, and at the other end in a multipoint plug. The terminal block

end of the cable is securely held in the base, just below the slip ring assembly column. From this terminal block, connections are made to the appropriate slip rings, by means of short insulated wires passing up through the slip ring column. Strain on the soldered connections of the slip rings is thus eliminated. Elimination of strain on the connections to the terminal block is accomplished by clamping the cable to the inside of the base casting, just before it passes out through the bottom of the base.

21. When the main case is mounted on the supporting column, the cable is passed down through the column and the plug (female) is brought out underneath and fastened to the underside of the platform by a clamp (see frontispiece).

Revolving assembly (housing).

22. The revolving assembly is contained in an aluminum housing. It includes the elevation and azimuth handwheels with associated gear trains, elevation rack, pinion, elevation scale, data transmitters and spring brush assembly, spirit level, push button cut-out switch and the potentiometer resistors. In the following description of each of these items, its location on or in the housing will be taken as viewed from the elevation handwheel side of the main case, i. e., the elevation scale is located at the top, right side of the housing.

23. The elevation and azimuth handwheels are located outside and on opposite sides of the housing. The azimuth handwheel is provided with a friction lock knob on the hub of the wheel, so that the housing may be locked in any desired position of azimuth.

24. The gear trains of the handwheels are located inside the housing. From there the motions of the handwheels are applied through chain drives and gearing to the pantograph drive assembly. By means of extension shafts this motion is also applied to the differential gearing of the corrector drive assembly.

25. The elevation rack assembly includes an axle which is located at the top of the housing and is horizontally mounted on sectional bearings. The upper halves of these bearings are removable so that the axle may be lifted from the housing. The lower halves of the bearings form an integral part of the main case housing. The axle, to which the horn assemblies are attached, may be locked in any position of rotation by means of a friction lock, located on top of the left bearing. The elevation rack is integral with the axle at the left end, and extends down that side of the main case, outside the housing. It is driven by means of a composition pinion gear, which serves to reduce gear noise. The elevation scale is rigidly attached to the elevation axle, at the right end, and is graduated in mils (0-1600).

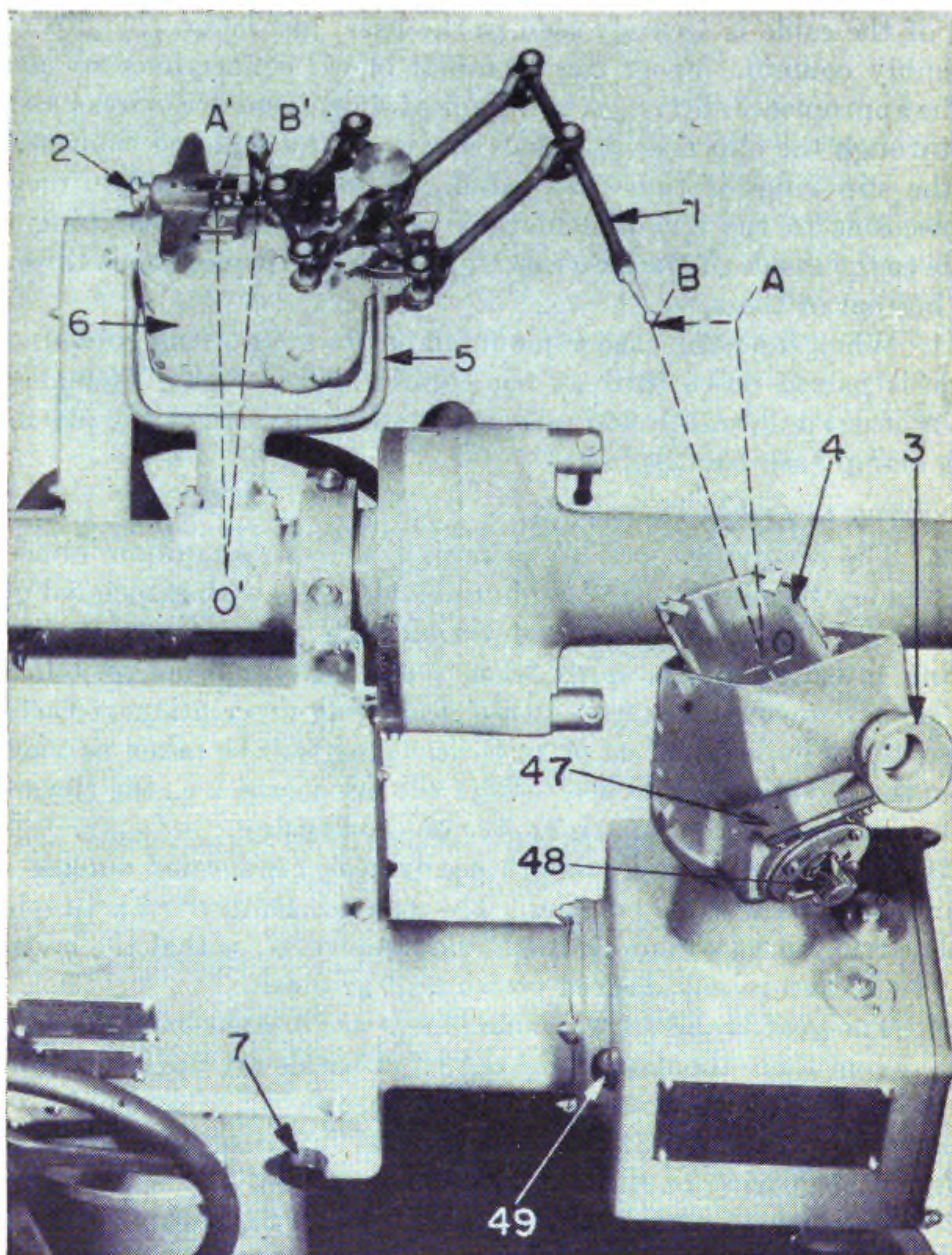


FIGURE 9.—PANTOGRAPH DRIVE ASSEMBLY.

- | | |
|-----------------------------------|-------------------------------------|
| 1. Multiplying pantograph. | 6. Ball corrector case. |
| 2. Target air speed setting knob. | 7. Self synchronous cut-out switch. |
| 3. Sight. | 47. Mirror lamp housing. |
| 4. Mirror. | 48. Mirror lamp rheostat knob. |
| 5. Yoke. | 49. Signal switch. |

26. The data transmitter assembly and the method of mounting it in the housing are described in a subsequent part of this section.

27. The spirit level is mounted on the housing, directly in front of the azimuth handwheel, and is of the bubble centering type.

28. The push button switch and the potentiometer resistors are

SOUND LOCATOR M2

mounted inside the main case housing. The switch button extends through the housing at the right of the elevation handwheel.

29. For servicing or parts replacement, the housing is provided with two cover plates, one in front of each handwheel.

B. Pantograph drive assembly

30. The pantograph drive assembly consists of two devices: (1) the speed corrector assembly, and (2) the parallax offset mechanism.

31. The pantograph drive case 6, figure 9, contains these two devices that control the pantograph. In the drive case, the final stages of the combination chain and gear drive from the elevation and azimuth handwheels correctly position the course indicator and the parallax offset mechanism. Thus the estimated target air speed and parallax offset corrections are "set in" and always maintained in the proper direction. The course indicator, parallax offset scale, and the pantograph are all mounted on top of the pantograph drive case so that they are readily accessible for adjustment during operation.

Speed corrector assembly.

32. The speed corrector assembly includes a model airplane called a course indicator, about four inches long and pivoted on a vertical shaft. The lower end of this shaft carries a caster, called the resolving ball caster roller, which rolls on the surface of a two-inch diameter resolving ball contained in pantograph drive case 6, figure 9. The function of this ball is explained in section II, Principles of Operation.

33. The model airplane (course indicator) carries an adjusting knob 2, figure 9, at its front end, connected to a screw running the length of the model. Mounted on this screw is a pantograph operating stud which carries an index mark. A speed corrector scale is along the left side of the model, graduated in miles per hour (0-400), for "setting in" the estimated target speed.

34. The short end of the pantograph structure contains a bushing which fits over the pantograph operating stud. The long end or arm of the pantograph structure carries a $\frac{3}{16}$ " diameter ball, called the pantograph pointer, which is positioned near the sight mirror. The image of the pantograph pointer is seen by the corrector operator in the mirror as he operates the corrector.

35. One function of the speed corrector assembly is to position the pantograph pointer ball in accordance with the direction of rotation of the resolving ball, as determined by the elevation and azimuth handwheel movements, and as modified by the setting on the speed corrector scale for estimated target speed. A second function of the assembly is

to serve as a visual indication of the general direction in which the actual target is flying, since the position of the model is always approximately parallel to that of the target. (The parallelism of speed corrector and target is more fully described in sec. II.)

Parallax offset mechanism.

36. The pantograph structure has an adjustable pivot and the mechanism for adjusting the position of this pivot point is called the parallax offset mechanism. It contains an arm called the parallax correcting arm, adjustment of which allows movement of the pantograph pivoting point over a range of slightly less than an inch.

37. This adjustment is to compensate for parallax, or the difference in pointing of the searchlight and of the sound locator because of their physical separation, as explained in section II. The correction must be proportional to the distance separating the searchlight and sound locator, and the direction of the correction effected by the parallax correcting arm must be in a direction parallel to that of the base line. This is accomplished by gearing between the parallax offset mechanism and the azimuth handwheel, so that rotation of the Sound Locator in azimuth rotates the parallax offset mechanism proportionately.

C. Corrector drive assembly

38. This assembly consists of two subassemblies: (1) the corrector drive mechanism, and (2) the open sight assembly. However, since these two subassemblies operate as a unit, they will be described as such. Assume that the horns are positioned so that the condition of binaural balance is obtained in azimuth and elevation, with respect to a sound source in space. It becomes apparent that a line midway between the azimuth and elevation horns and pointing in the same direction as those horns will, if extended into space, be directed at the apparent sound source. This line is indicated as $O'A'$ in figure 9, and would be directed at the apparent target position. For practical purposes it is better to transfer this sighting point to the position shown as point O . The sound lag correction setting of the pantograph pointer is then represented by AB , the length of which is determined by the setting $A'B'$ of the sound lag correction screw. It is to be noted that the use of the pantograph requires the offset $A'B'$ to be opposite the actual offset AB . If the lines OA and OB were extended into space, line OA would pass through the apparent target position and line OB would pass through the actual target position.

39. After the parallax correction has been added to the sound lag

SOUND LOCATOR M2

correction, the above statement is no longer true, but the line *OB* represents, instead, an imaginary line from the *searchlight* to the actual target position.

40. Movement of the sight mirror in azimuth is controlled by (1) the azimuth handwheel, which turns the entire corrector assembly, and (2) the corrector operator's handle (see 34, frontispiece) which is moved in azimuth to keep the image of the pantograph pointer centered on the cross lines of the mirror. These two controlling motions in azimuth are combined in the differential gearing and the resultant movement is applied to the azimuth data transmitter, which transmits, electrically, the correct azimuth angle to the searchlight data receiving system.

41. Movement of the sight mirror in elevation is controlled by (1) the elevation handwheel which, through a differential gear, elevates the mirror by an amount equivalent to the elevation of the horns, and (2) by the corrector operator's handle knob 34 (see frontispiece) which is turned so as to elevate or depress the mirror to keep the pantograph ball centered on the cross lines of the mirror. These motions in elevation are combined in differential gearing and the resultant motion is applied to the elevation data transmitter, which transmits the correct elevation angle of the target to the searchlight.

42. The azimuth and elevation handwheels are each connected through a differential to the data transmitter. The third leg of each of these differentials is actuated by the corrector, as described in the two preceding paragraphs.

43. With only sound lag correction "set in," the elevation and azimuth positions transmitted to the searchlight are the positions of the target from the sound locator. With both sound lag and parallax corrections "set in," the reference point of the target position indicated is transferred from the sound locator to the searchlight. This is true for any angular azimuth relation between the sound locator, searchlight, and target.

44. A lamp ¹ (see 47, fig. 9) has been provided to illuminate the cross lines on the mirror and the pantograph pointer, with a rheostat,¹ 48, to regulate the intensity of illumination as required by conditions. The rheostat serves also as the light switch. Its "OFF" position is marked. Under certain night weather conditions the illumination from the sky may be nearly as strong as the self-luminosity of the cross lines and pointer, so that they are distinguished with difficulty unless the lamp is used.

45. Mounted on the corrector drive housing is the signal switch ¹ 49,

¹ Not used on sound locators with serial numbers below 376.

a push button designed to operate a buzzer in the control station. The function of this signal circuit is to notify the control station operators that the sound locator operators are tracking a target.

IV—DATA TRANSMISSION SYSTEM

46. The complete data transmission system includes: (a) data transmitters; (b) slip rings, brushes, and terminal blocks; (c) a cut-out switch and resistors; and (d) control cables.

47. The azimuth zero reference line for the transmission of data from the sound locator to the searchlight is the base line between these two units, and the elevation zero reference line is in the horizontal ground plane at the sound locator. Figure 32 shows the wiring of the data transmission system. Two¹ of the cable conductors are used to connect the signal button at the sound locator with a buzzer (when installed) at the control station, in addition to their use in the data transmission system.

A. Data transmitters

48. There are two data transmitters, one for azimuth and one for elevation. The secondary voltages of the transmitters are functions of the displacement, in rotation, of the rotor with respect to the stator. These voltages can then be used by the searchlight data receiving system to indicate that the receiving system and the searchlight are synchronized in azimuth and elevation with the corresponding positions of the data transmitters. This is the same approved type of control that has been used in previous equipment of this character.

49. The transmitters are mounted in and completely enclosed by a cast aluminum case, having a removable cover for servicing or parts replacement. The case as a unit is mounted inside the main case housing on composition, vibration-damping blocks. The transmitter rotor shafts are vertical and extend through the bottom of the case. The driving gears for the rotors are mounted on a spider which is, in turn, attached to the respective shafts. The gears are all insulated from the spiders by rubber, so that only a negligible amount of rotor vibration is transferred to the associated gear trains or to the main case.

50. The transmitters are controlled by the resultant movements of the respective handwheels as well as by the corrector drive mechanism. Reference should be made to paragraphs 40-42 for a more detailed explanation of this control system.

¹ Not used on sound locators with serial numbers below 376.

SOUND LOCATOR M2

B. Spring brush and terminal block assemblies

51. The secondary voltages of the data transmitters are transferred, by means of spring brushes, to the eight slip rings mentioned in paragraph 16. These rings are in the lower section of the transmitter case. They are stationary with respect to the base and column of the sound locator and, during azimuth adjustments, the eight brushes revolve around them. The rings are wired to terminals in a circular 10-point terminal block, to which also is connected the upper end of a short extension cable.

52. Transmitter power terminals are brought out to another terminal block mounted on the lower case section. From this terminal block connections are made to the listening switch, the signal switch, and the potentiometer resistors.

C. Cut-out switch

53. The transmitter case and rotor vibrations have been isolated to a great extent by the use of vibration damping material. However, it may be possible under certain conditions to detect a slight residual a-c hum from the transmitters. While this hum does not affect some listeners, others, when trying to pick up the target sound at extreme ranges, may be bothered by it. For this reason, the push button 7, figure 9, has been provided. The switch which is operated when this button is depressed connects resistors into the circuit so as to reduce the hum to inaudibility. It does this by connecting two 40-watt, 146-ohm resistors in parallel with each other but in series with the data transmitters, and at the same time connecting a third, 45-ohm resistor in parallel with the data transmitters.

54. Tests have shown that the accuracy of synchronization of the searchlight with the data transmission system is not impaired if the sound locator is operated with the push button held in. However, the voltage reducing resistors are not designed for continuous operation and operators are advised that if they find it necessary to use the push button switch, it should be held in only for the period of time required to detect the sound of the target.

D. Cables

55. A nine-conductor extension cable, $7\frac{3}{4}$ feet long, is used for the internal connection between the main case and the external connection point. This cable is connected at its upper end, as shown in figure 32, to a terminal block and terminates at the lower end in a 10-point plug. The cable extends downward through the hollow

column of the sound locator and passes under the platform to a clamp near the edge.

56. Nine hundred feet of nine-conductor flexible, rubber-covered cable are supplied in two 450-foot lengths. Each length terminates in nine-point male and female keyed plugs. Each plug is provided with a protecting flange and a clamp for locking it to a mating plug. Each length of cable is carried on a drum, and both drums are carried in a portable reel provided with two crank handles.

V—PLATFORM AND COLUMN

57. The circular platform is constructed of laminated wood, the top surface being covered with battleship linoleum. The edges of the platform are bound with metal for strength, to prevent splitting or breaking. In the center of the platform is a suitable sized hole, to allow passage of the extension cable and receptacle. A metal ring, concentric with this hole, is bolted to the platform and supports the weight of the column and the corrector assembly.

58. Four equally spaced adjustable jacks, placed around the outside edge of the platform, support the weight of the sound locator assembly. The tops of the jacks are recessed below the level of the platform and accommodate the jack wrench, provided in the spare parts box, for adjustment of jacks when leveling the sound locator.

59. On the bottom surface of the platform, near its outer edge, is a hinged clamp for securing the plug of the extension cable.

60. The column is a hollow aluminum casting. At assembly it is mounted on the platform, and securely fastened to it by four equally spaced mounting stud assemblies. These studs pass through the bottom flange of the column, into tapped holes in the supporting ring. In a similar fashion studs at the top of the column are used to secure the base of the main case to the column.

VI—CHARACTERISTICS

61. The sound locator M2 has the following characteristics:

A. Limits of operation

- (a) Azimuth, 0-360° (0-6400 mils).
- (b) Elevation, 0-90° (0-1600 mils).

B. Corrections, maximum

- (a) Azimuth, $\pm 74.5^\circ$ (1,325 mils).
- (b) Elevation, $\pm 32.4^\circ$ (575 mils).

SOUND LOCATOR M2

C. Power requirements

(Includes power required by zero reader data system)

Approximately 65 watts, 115 ± 15 volts, 60 cycle a-c.

D. Handwheels—mils/revolution

- (a) Azimuth, ratio 18-1 = 355.55 mils/rev.
- (b) Elevation, ratio 18-1 = 355.55 mils/rev.

SECTION IV OPERATION

I—ASSEMBLING THE SOUND LOCATOR

1. The complete sound locator is broken down into six component parts for transportation. These parts and the covers with their approximate weights are as follows:

Two horn assembly, 90 lbs.

Single horn assembly, 55 lbs.

Corrector assembly with carrying case and spare parts, 330 lbs. (total).

Column, 30 lbs.

Platform, 130 lbs.

Cable and cable reel, 395 lbs.

Horn covers (3), 36 lbs.

The sound locator is carried on a transporting truck, in conjunction with the searchlight and controls station.

2. Unload the equipment and assemble the sound locator as follows:

a. Carry the platform to the sound locator position and place it so that the leveling jacks will have firm footing. Set it up and level it approximately.

b. Place the column on the platform and bolt it down. (See 18 and 19, fig. 10.)

c. Place the corrector assembly on the column, the cable plug 17 being first dropped down through the pedestal as shown in figure 10. Bolt the unit in place. Remove transportation bracket 20, loosen elevation friction clamp 14, figure 13, turn to maximum elevation and tighten elevation clamp, so as to lock the elevation axle in position.

d. Bolt the horn assemblies in place as shown in figures 11 and 12, assembling the single horn unit 21 first. It will be found that the horns are handled with greater ease if the canvas covers are not removed until after the horns have been mounted in place. Note

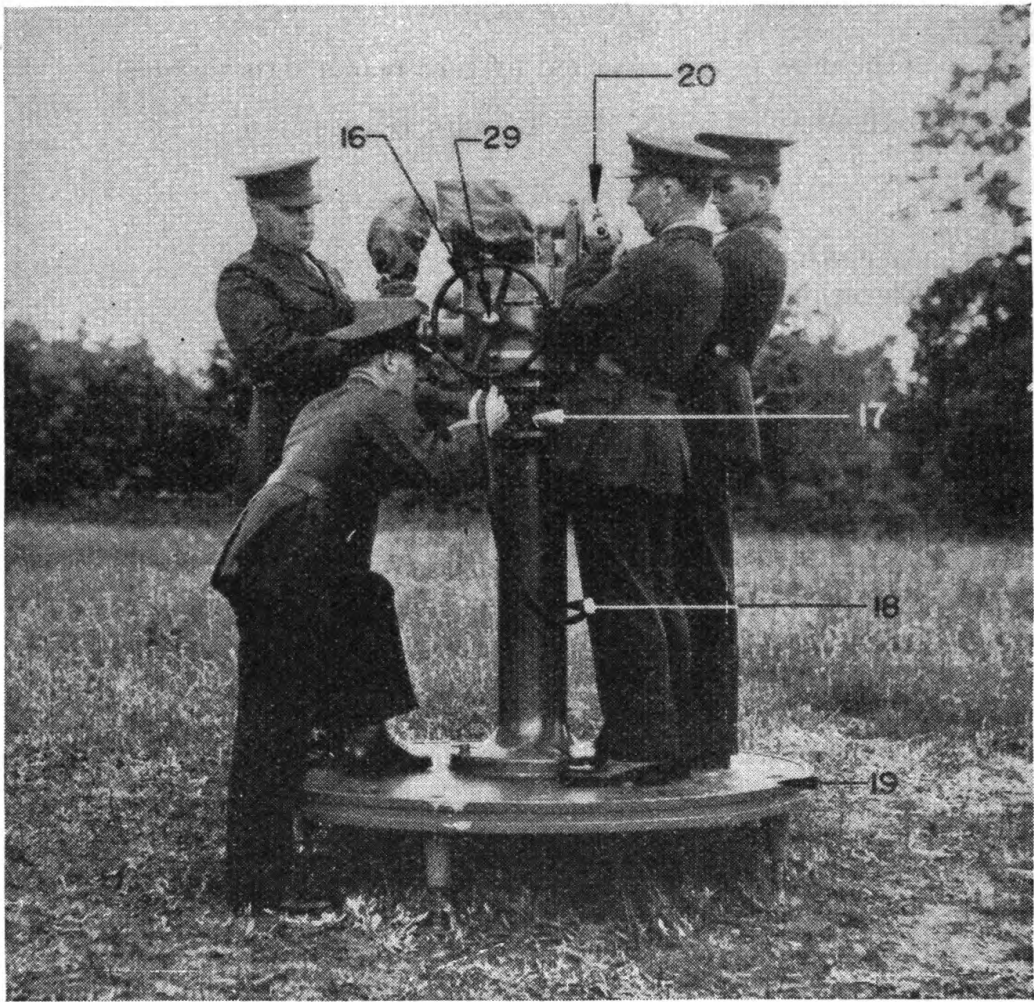


FIGURE 10.—PLACING CORRECTOR ASSEMBLY ON COLUMN.

- | | |
|--------------------------|-----------------------------------|
| 16. Corrector assembly. | 19. Platform. |
| 17. Cable plug (female). | 20. Transportation bracket. |
| 18. Column. | 29. Azimuth handwheel clamp knob. |

that markers on the hubs of the horn arms show the location of the holes for the dowel guide pins.

e. Mount the pantograph on the drive case as shown in figure 13. Secure pantograph in position by means of knob 7.

f. Unreel one length of control cable. Connect its male plug to the female plug 32, see frontispiece, of the extension cable underneath the sound locator platform. Clamp this connection to the under side of the platform. Connect direct, if the separation between sound locator and searchlight permits, or through the second length of control cable if the separation is between 450 and 900 feet. In order to get as far away as possible from the noise of the power unit at the searchlight, the full 900 feet of separation should be utilized whenever possible.

SOUND LOCATOR M2



FIGURE 11.—ATTACHING AZIMUTH HORN TO CORRECTOR ASSEMBLY.

16. Corrector assembly.

21. Azimuth horn.

g. Adjust the leveling jacks until the bubble level 13, figure 13, indicates that the platform is horizontal. It is necessary that all four jack pads be firm against the ground. This condition may be checked by walking around the platform to detect any tendency to rock or settle. The sound locator is now ready for orientation.

II—ORIENTING AND SYNCHRONIZING IN AZIMUTH

3. The searchlight and sound locator must be oriented to a common base line and synchronized in azimuth and elevation. It is assumed that the searchlight equipment has been set up and that proper connections have been made as prescribed in the operator's manual for that equipment.

4. Before commencing the operations outlined below, if the control station is equipped with searching mechanism, make certain that the

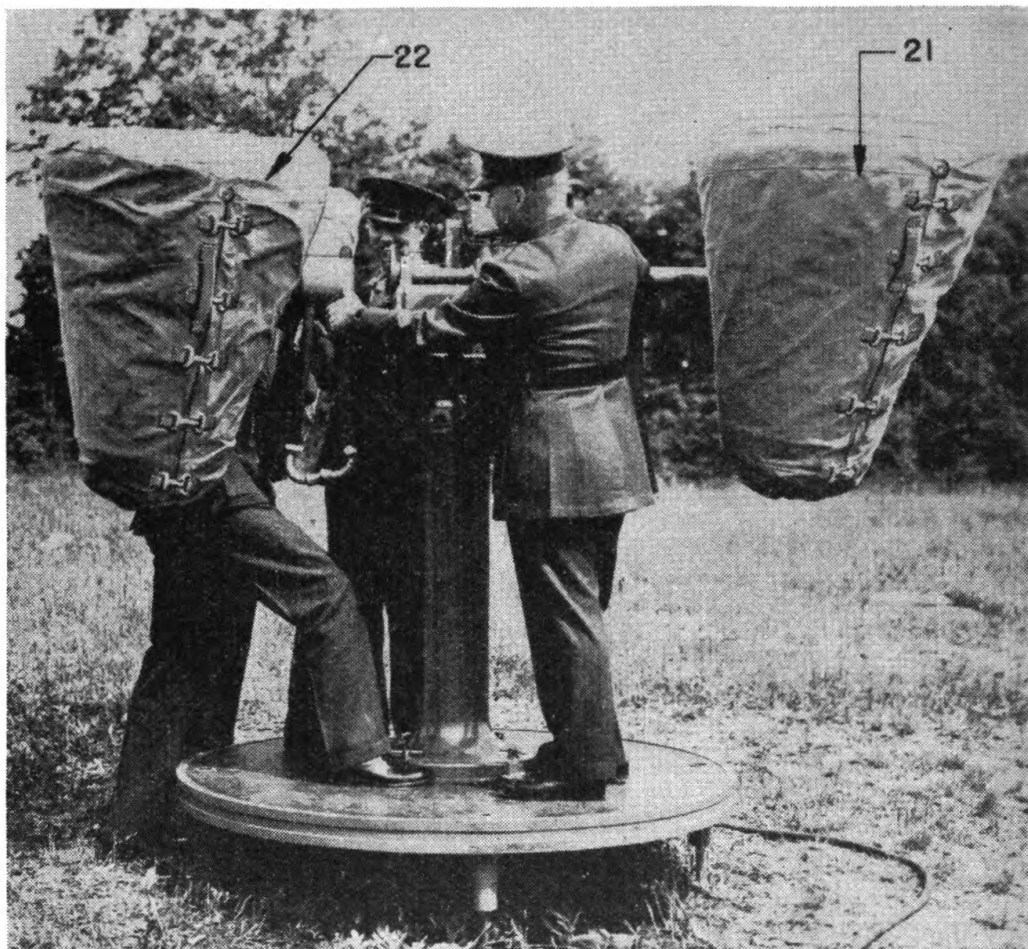


FIGURE 12.—ATTACHING ELEVATION AND COMMON HORN UNIT TO CORRECTOR ASSEMBLY.

21. Azimuth horn.

22. Common (az. and elev.) horn.

searching control is at zero position as instructed in the operator's manual supplied with that equipment.

A. The searchlight

5. Disengage the azimuth clutch knob by pulling the azimuth clutch handle in direction indicated as OUT.

6. Turn searchlight in azimuth until it points at the pedestal of the sound locator, sighting by means of the orienting sights on the searchlight.

7. Reengage the azimuth clutch knob by pushing the clutch handle in direction indicated as IN.

8. Set the searchlight azimuth scale to 3,200 mils by loosening the azimuth scale, located at the base of the searchlight, and turning it until 3,200 on the scale is under the index pointer. Tighten the

SOUND LOCATOR M2

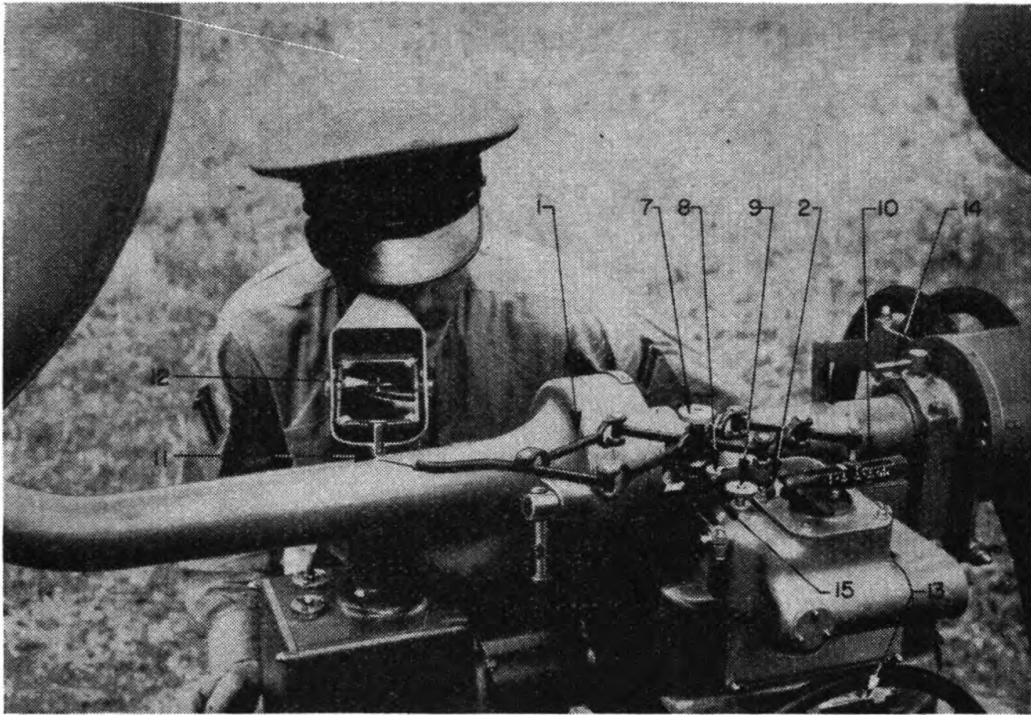


FIGURE 13.—THE CORRECTOR OPERATOR IN ACTION.

NOTE: For convenience of photographing the listeners are not shown at their posts.

- | | |
|------------------------------------|----------------------------------|
| 1. Multiplying pantograph. | 11. Pantograph pointer and ball. |
| 2. Target air speed setting knob. | 12. Sight mirror cross lines. |
| 7. Pantograph attaching stud knob. | 13. Level. |
| 8. Parallax cam. | 14. Elevation clamp. |
| 9. Declutching gear. | 15. Parallax scale. |
| 10. Target air speed scale. | |

azimuth scale and swing searchlight in azimuth to zero position, as indicated by the pointer index and scale.

9. Start the power plant and turn the d-c switch at the control station to ON. In this way the distant electrical control system is used to lock (electrically) the searchlight in the zero (0) position to which it has just been set.

B. The sound locator

10. Set the sound locator elevation to zero and keep it so throughout this part of the operation.

11. Set target speed to zero by means of knob 2, figure 9.

12. Set the parallax offset scale 15, figure 13, to zero.

13. Loosen azimuth handwheel clamp knob 29, figure 10, and point sound locator at the searchlight. By using the corrector sight and by adjustment of the corrector arm, corrector knob, and azimuth handwheel, get the images of the pantograph pointer and of the rear of the searchlight drum to coincide at the center of the cross lines of

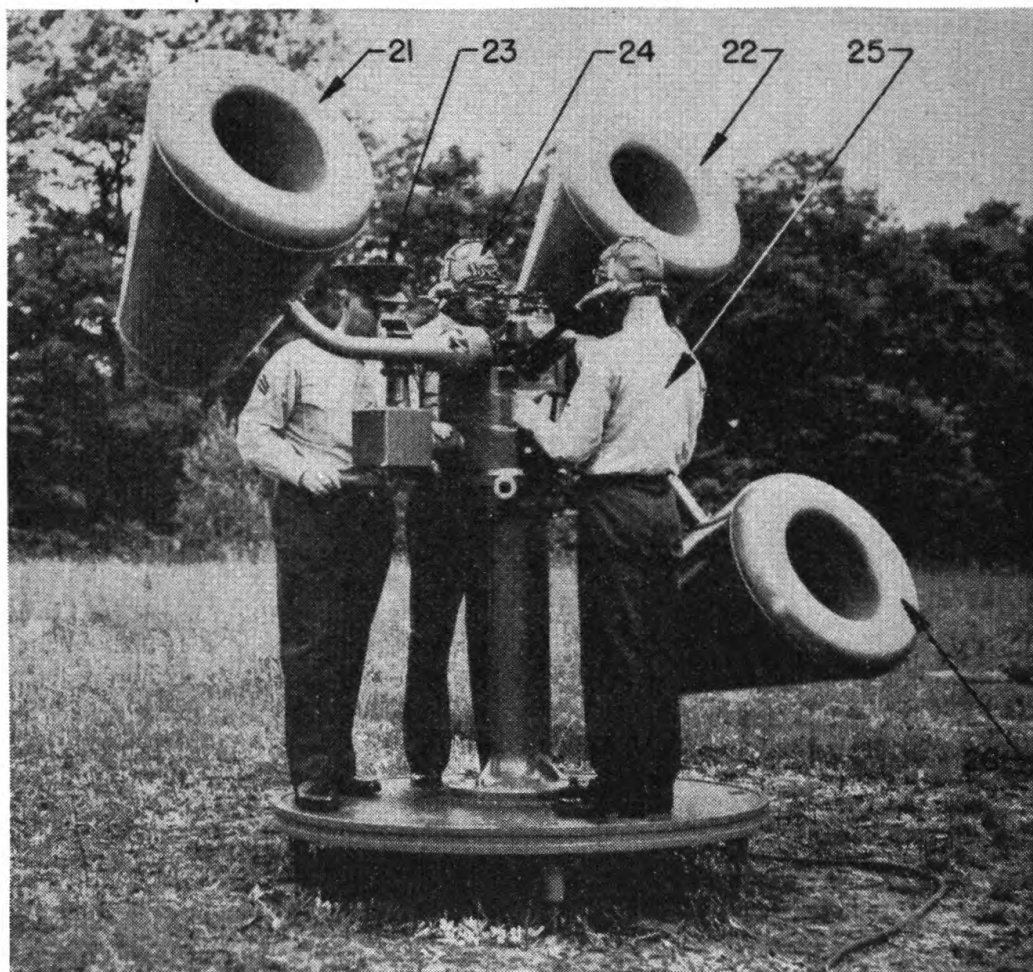


FIGURE 14.—TRACKING A TARGET.

- | | |
|--|-------------------------|
| 21. Azimuth horn. | 24. Elevation listener. |
| 22. Common (azimuth and elevation) horn. | 25. Azimuth listener. |
| 23. Corrector operator. | 26. Elevation horn. |

the mirror. If the searchlight is not on the same level as the sound locator this will not be possible and, after the pointer has been centered, the mirror will have to be moved in elevation only by means of the corrector knob until the image of the searchlight can be seen in the mirror. Complete the orientation by use of the azimuth hand-wheel. Be careful not to disturb the corrector handle during completion of orienting and synchronizing *in azimuth*.

14. Tighten azimuth clamp to hold the sound locator in position.

15. Set the sound locator azimuth scale to zero by loosening the scale and turning it until zero on the scale is under the index pointer.

16. Recenter the pantograph pointer in the mirror by use of the corrector knob.

SOUND LOCATOR M2

17. Push down on the declutching gear 9, figure 13, and rotate the parallax cam 8, until the arrow on top of the cam points directly at the searchlight. Then remesh gearing.

C. The control station

18. Position the control station according to the instructions contained in the operator's manual supplied with that equipment.

19. Swing the control unit around on the tripod until it points directly at the searchlight. Sight at the center of the searchlight drum through the binoculars, as well as through the open sight provided.

20. Set the control station to zero azimuth in accordance with the instructions supplied with that equipment.

III—ORIENTING AND SYNCHRONIZING IN ELEVATION

A. The searchlight

21. Turn the searchlight elevation control clutch lever to HAND position and set searchlight to zero elevation by hand.

22. Lock (electrically) the searchlight in zero elevation position by turning the clutch lever to the D. E. C. position.

Caution: Do not force the clutch lever. If it will not move easily into the D. E. C. position, keep a slight pressure on the lever and turn the motor coupling slowly, by hand, until the clutch lever engages.

B. The sound locator

23. Lock the sound locator at zero elevation by means of clamp lock 14, figure 13. With zero speed and parallax settings, center the pantograph pointer on the cross lines of the sight mirror. Be careful not to disturb the corrector handle thereafter until completion of orienting and synchronizing in elevation.

NOTE: During this operation the sound locator may be at any convenient azimuth setting, and need not be aimed at the searchlight.

C. The control station

24. Set the control station to zero elevation in accordance with the instructions supplied with that equipment.

IV—PREPARING TO TRACK A TARGET

25. Set in estimated target air speed by means of knob 2, figure 9. This information is obtained by the battery commander from outpost listening stations, or from his knowledge of the expected type of target, etc.

26. Set in parallax offset on scale 15, figure 13.

This information is obtained by the battery commander from the graph, figure 30, or from the duplicate which is attached to the corrector drive housing.

27. The corrector operator 23, figure 14, will then take his place at the corrector position.

28. The listeners, in the meantime, will don their helmets, a sketch of which is shown in figure 15, and adjust the lacings to provide for maximum soundproofing compatible with comfort, in the following manner.

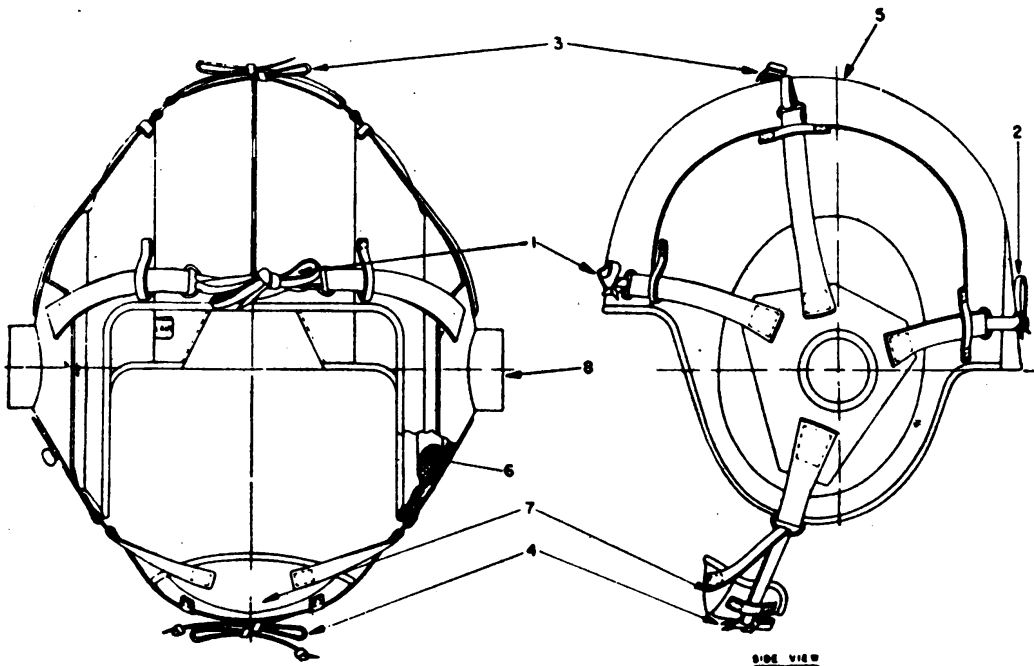


FIGURE 15.—LISTENER'S HELMET (Sperry drawing No. 643904-A).

- | | |
|----------------------------|------------------------|
| 1. Front adjusting lacing. | 5. Crown of helmet. |
| 2. Rear adjusting lacing. | 6. Ear cup. |
| 3. Crown adjusting lacing. | 7. Leather chin cup. |
| 4. Chin adjusting lacing. | 8. Metal ear coupling. |

a. Place the helmet on the head, making certain that the crown 5 is snugly fitted to the contour of the head.

b. Adjust front 1 and rear 2 lacings to insure proper placement of ear cups 6 (the large padded cups which surround the entire ear) in such a manner that they are snugly fitted to the side of the head. Make certain that the inner fittings of the ear cups are directly in line with the tragus (the prominence in front of the external opening of the ear).

c. Adjust crown lacings 3 to insure proper vertical placement of ear cups with respect to the tragus of the ears.

SOUND LOCATOR M2

d. Adjust chin strap 4 so that the point of the chin fits into the small leather cup 7. Then fasten lacings in such a manner that the front edge of the helmet is snugly fitted to the facial contours.

Caution: Correct helmet fit is highly important, so all listeners should be required to adjust and fasten their helmets as described. To check for proper fit, the listener can wear his helmet and, without connecting it to the sound tracks, listen to a sound source of known direction. This will indicate whether the binaural sense of direction is normal. If it has been affected by improper adjustment, the helmet should be refitted. This check should be made prior to operation of the sound locator, since any error in binaural sense of direction will result in an error in apparent sound source direction when operating the instrument.

29. When the helmets have been properly adjusted, the listeners 24 and 25, figure 14, should place themselves on the platform and snap the couplings into their ear pieces. The sound locator and operating personnel are now ready for operation. In operation of the sound locator it is essential to preserve silence to avoid distraction and confusion of the listeners.

V—TRACKING A TARGET

30. Rotate the azimuth and elevation handwheels so that constant binaural balance of the sound source is maintained in the ears of each listener. To accomplish this the azimuth listener should move the top of the azimuth handwheel toward his right when the sound seems to be louder in his right ear. This will rotate the sound locator toward the apparent source. The elevation listener should also move the top of his handwheel toward the right when the sound seems to be louder in right ear. This will elevate the sound locator. Since the upper horn is connected to his right ear piece, this in his case also will direct the sound locator toward the apparent source.

31. Move the corrector handle and knob in such a manner as to keep the image of the pantograph pointer continuously centered on the cross lines of the sight mirror.

32. The listeners should endeavor to follow the target with the sound locator as smoothly and accurately as if they were pointing the finger at the target, particularly while the searchlight is lighted. They should keep in mind at all times that every erratic or sudden movement of either handwheel is reproduced in the motion of the pantograph pointer, to the confusion of the corrector operator. He on his part should remember that the target motion actually is smooth and continuous, and should equalize out, in his operation of the cor-

rector, any irregularities he may see in the motion of the pantograph pointer.

33. One exception to this rule of conduct for the listeners may be made when a listener, to assure himself of the accuracy of his binaural balance, momentarily oscillates his handwheel about the point of balance.

34. A much improved quality of performance of the team in tracking the target is secured if its members are each trained in all three operations, as suggested in section VI.

SECTION V

ROUTINE MAINTENANCE

I—GENERAL

1. The following instructions are provided as a guide for the routine maintenance of the sound locator M2. A sample inspection report form for checking equipment into stock and for testing operation of parts is contained in appendix C. Complete overhaul or parts replacement should be undertaken only by qualified personnel. Detailed instructions for such overhaul and parts replacement are contained in TM 9-1660, Ordnance Maintenance, Sound Locator M2.

II—TRANSPORTATION

2. The sound locator is provided with a suitable box for packing and transporting the corrector assembly. The method of packing this assembly is illustrated in figures 16 and 17. Canvas covers and metal caps are provided for the horns and a canvas cover is provided for the corrector mechanism. These caps and covers should be put on when the equipment is not in use. The hinged clip on the bottom of the platform should be kept tightly closed during transportation to avoid damage.

3. No attempt should be made to move the sound locator after the horns have been mounted on the corrector assembly. If it is necessary to change the placement, the horns should be dismounted, carried to the new emplacement, and again mounted on the corrector assembly.

4. No part of the corrector assembly or horn assemblies should be subjected to undue shock through dropping, collision or other contributing factor. If such shock occurs, and the equipment fails to function properly after routine assembly and check, ordnance personnel should be notified immediately.

SOUND LOCATOR M2

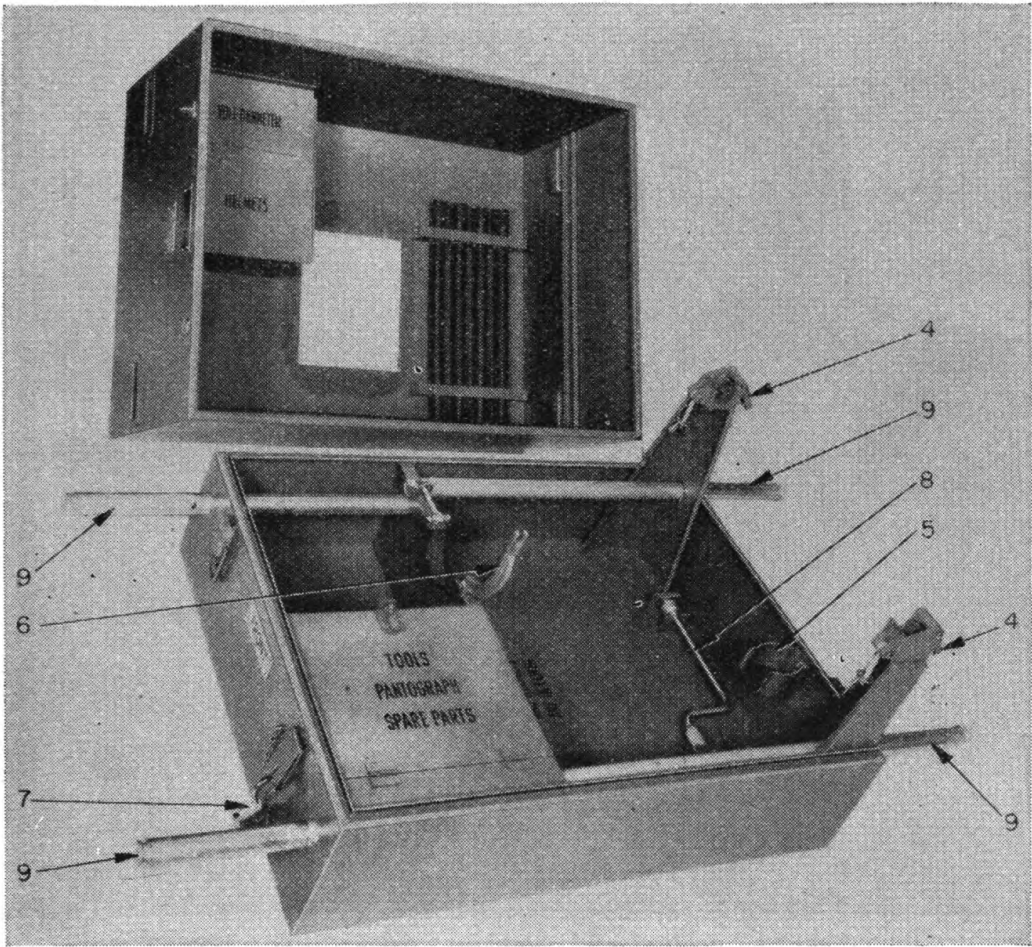


FIGURE 16.—STOWAGE BOX FOR CORRECTOR ASSEMBLY.

- | | |
|---|----------------------------|
| 4. Clamp lock for transportation bracket. | 7. Lock and keys. |
| 5. Spring clip for cable plug. | 8. Jack wrench. |
| 6. Clamp lock for main case. | 9. Transportation handles. |

III—CLEANING

5. The surface of the metal sight mirror should not be cleaned any oftener than necessary, because of the danger of scratching the highly polished surface. However, dust which settles on this surface may be removed by soft cotton.

6. If the mirror becomes greasy, it may be cleaned with soft cotton moistened with alcohol.

7. In the event that the mirror surface becomes exceptionally dirty during servicing or field operations, the surface may be cleaned by mixing three ounces of precipitated chalk with eight ounces of a good grade of denatured alcohol. Place a small amount of this mixture on a piece of absorbent cotton which has been previously moistened

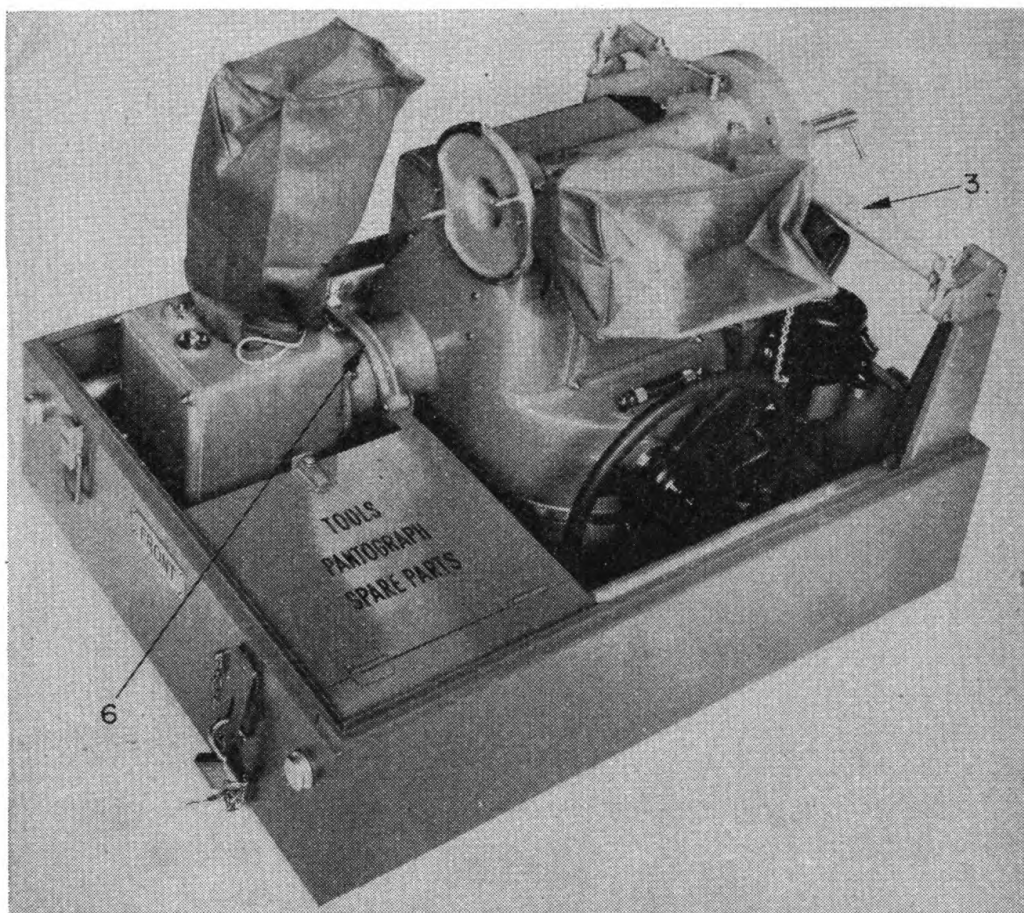


FIGURE 17.—CORRECTOR ASSEMBLY IN STOWAGE BOX.

3. Transportation bracket.

6. Clamp lock for main case.

with alcohol, and rub lightly over the surface of the mirror using a circular motion. After the paste is partly dry, remove with clean, dry absorbent cotton. Precipitated calcium carbonate may also be used for this purpose.

8. Surfaces of the slip rings should be inspected periodically and, if necessary, cleaned with carbon tetrachloride and a soft cloth. This cloth should be kept separately and should not be used for any other purpose. It should be washed frequently, making certain that all soap is rinsed out.

9. The rubber eye guard on the open sight should be removed periodically, washed in warm water and dusted over with French chalk, or equivalent, as a preservative.

10. The horns and acoustical system should be kept clean of water, dirt, or other foreign matter at all times. This does not mean that the equipment may not be used during rain, but that it should be checked for this, prior to packing or storage.

SOUND LOCATOR M2

IV-CHECK TESTS

A. Course indicator

11. Tighten elevation lock and loosen azimuth lock.

12. Train clockwise in azimuth. The course indicator should align itself parallel to the elevation axle and point to the right. Train counterclockwise. The course indicator should again align itself parallel to the elevation axle but pointing to the left.

NOTE: The left and right directions of the course indicator are to be taken as viewed from the elevation operator's side of the sound locator.

13. Tighten azimuth lock and loosen elevation lock.

14. Increase elevation. The course indicator should align itself perpendicular to the elevation axle and point toward the elevation operator.

15. Decrease elevation. The course indicator should align itself perpendicular to the elevation axle and point away from the elevation operator.

B. Parallax pointer

16. Tighten elevation lock and loosen azimuth lock.

17. Rotate the sound locator through 360° , noting the position of the parallax pointer prior to this rotation. The arrow should point in the same direction regardless of azimuth movements of the sound locator.

C. Pantograph and sight mirror

18. Set instrument to zero elevation and zero azimuth, and lock in position.

19. Set speed and parallax offset scales to zero.

20. By means of corrector handle and knob, center pantograph pointer on cross lines of mirror. Rotating the course indicator through 360° (by hand) it should be possible to maintain the image of the pantograph pointer on the cross lines of the mirror at all times, within a tolerance of one-half ball diameter, without movement of the corrector handle or knob.

21. Loosen the azimuth lock, keeping elevation locked.

22. Center the pantograph pointer on the cross lines of the mirror by means of the corrector handle and knob.

23. Assuming that the sound locator has been properly and accurately leveled, select a target at a suitable distance and level with the center of the pantograph mirror. Look into the mirror toward the target. Adjust the azimuth position of the instrument by the azi-

muth handwheel, if necessary, attempting to get the image of the target in the exact center of the mirror. If the instrument is in correct adjustment and the pointer is not bent vertically, the target should be seen behind the ball so that its center is hidden by the ball.

24. Tighten the azimuth lock and loosen the elevation lock.

25. Increase elevation to 1,600 mils. Pantograph pointer should remain centered on the cross lines of the mirror to within $\frac{1}{2}$ the diameter of the pointer, without movement of the corrector handle or knob.

D. Over-all tests (problems)

26. *Problem No. 1.*—Orient and synchronize the sound locator and searchlight in the usual manner. Set all controls in elevation and azimuth at zero and all corrections at zero, on both sound locator and searchlight. Tighten the sound locator azimuth handwheel lock. Set the target speed on the course indicator at 400. Increase the elevation of the sound locator to 800 mils. (The course indicator should now point toward the elevation side of the sound locator with its axis at right angles to the elevation axle of the sound locator.) Elevate the searchlight by hand to 1355 mils. Turn the corrector knob of the sound locator until the elevation zero reader on the searchlight is centered. Now observe the sound locator corrector sight. Its pantograph pointer should be centered in the cross lines of the mirror within one-half ball diameter.

27. *Problem No. 2.*—Orient and synchronize, and set all controls and corrections to zero as before. Set target speed at 400, and elevation at 800. To simulate a target course of 4800 mils, turn the sound locator in azimuth to 4800 mils in a counterclockwise direction, then return it smoothly in a clockwise direction to zero azimuth. (The course indicator should now point parallel to the elevation axle of the sound locator and to the right.) Elevate the searchlight by hand to 687 mils and rotate it in azimuth to 659 mils. Turn the corrector handle and knob on the sound locator until the elevation and azimuth zero readers on the searchlight are centered. Now observe the sound locator corrector sight. Its pantograph pointer should be centered in the cross lines of the mirror within one-half ball diameter.

28. Additional problems are in appendix C.

V—LUBRICATION

29. Referring to figure 18, points 38 are lubrication points. Periodic inspection and lubrication will insure proper functioning of the equipment. It is recommended that an instrument oil be used for this purpose.

SOUND LOCATOR M2

30. Points 40 and 41, figure 18, indicate chain drives for operating the pantograph drive assembly. Periodic inspection and greasing of these chains should be made to insure proper operation. Removal of the cover plate 45, figure 19, will provide access to this section. It is recommended that Andok C grease (S. O. N. J.) be used for this purpose. In an emergency, however, if this is not available, a good grade of petrolatum (vaseline) may be substituted.

Caution: Care should be exercised to prevent application of too much grease during this operation, to lessen any possibility of the excess lubricant being thrown onto the slip ring assembly.

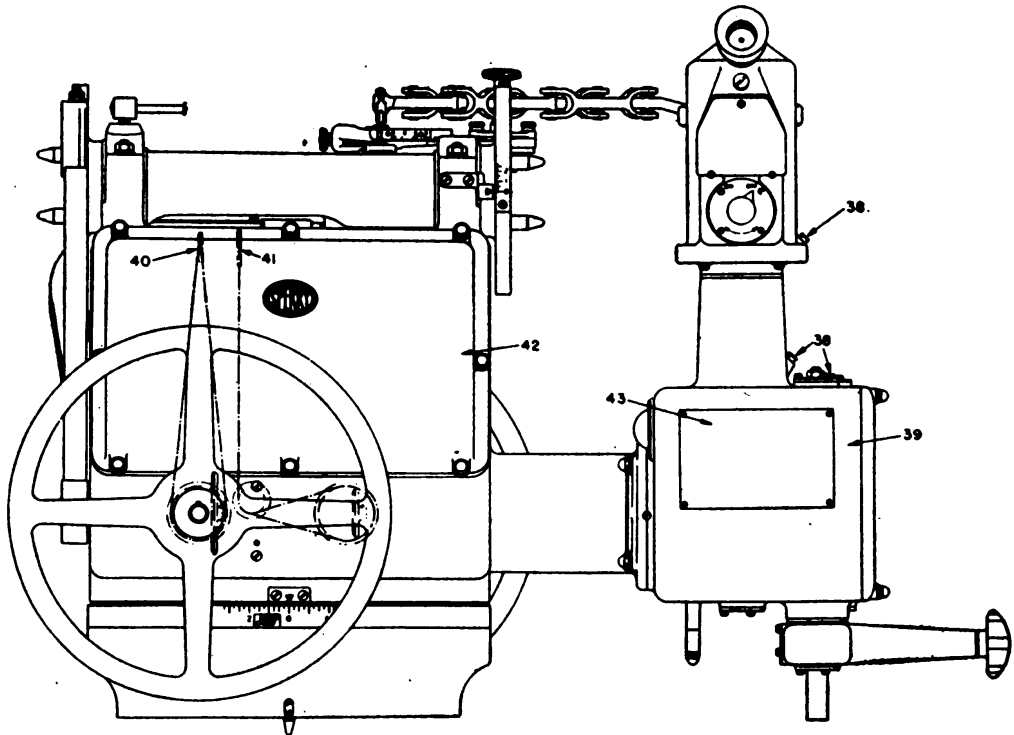


FIGURE 18.—FRONT VIEW—CORRECTOR ASSEMBLY (Sperry drawing No. 644129-B).

- | | |
|------------------------------------|--------------------------------------|
| 38. Oil cups. | 41. Course analyzer elevation drive. |
| 39. Corrector drive assembly. | 42. Front cover plate. |
| 40. Course analyzer azimuth drive. | 43. Parallax offset graph. |

31. Differential gears and ball races have been lubricated at the factory and no attention need be given these points except by authorized ordnance personnel during overhaul periods. For lubrication for use at extreme temperatures see TM 9-1660, Ordnance Maintenance, Sound Locator M2.

Caution: Particular care should be taken to prevent inclusion of any foreign matter within the main case during servicing operations.

32. All operating personnel should be cautioned against tampering

with the mechanisms of the sound locator, especially those of the corrector drive assembly and the pantograph drive assembly.

33. Plugs and receptacles should be kept clean and, when not in use, should have their protecting caps bolted on tightly.

34. If instrument is placed in storage for an extended period of time, the handwheels should be turned through one or two revolutions about once a month for the duration of the storage period.

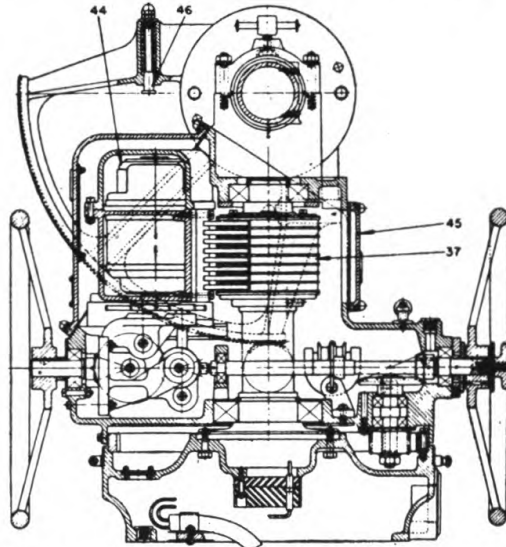


FIGURE 19.—CROSS SECTION OF MAIN CASE (Sperry drawing No. 644154-B).

37. Slip ring assembly.

45. Rear cover plate.

44. Self-synchronous data transmitters.

46. Spring loaded elevation stop.

VI—ACCESSORIES

35. The following accessories are supplied with the sound locator M2.

<i>F. A.</i>			
<i>Part*</i>	<i>Drawing</i>	<i>Number</i>	<i>Description</i>
<i>No.</i>	<i>No.</i>	<i>Required</i>	
644128		1	Sound locator assembly, complete with two medium size helmets
800686	B-138257	2	Cable assembly
643939	D-43105	1	Cable reel and cart
89413	D-43085	3	Horn covers (canvas)
800687	B-138258	3	Horn caps (metal)
89414	B-138216	1	Pantograph drive cover (moleskin cloth)
89415	B-138217	1	Sight cover (moleskin cloth)
75636	C-70212	1	Main mechanism cover (canvas)
76334	C-70229	1	Transportation bracket assembly
644357		1	Stowage box

*Sperry part number.

SOUND LOCATOR M2

<i>F. A.</i>			
<i>Part*</i>	<i>Drawing</i>	<i>Number</i>	<i>Description</i>
<i>No.</i>	<i>No.</i>	<i>Required</i>	
801667		1	List of stowage box contents
801099		1	Pantograph case
643940	D-43106	2	Helmets, complete (large size)
165840	A-177757	4	Ear pad bushing assemblies
801098		1	Spare parts box
153439		2	Stowage box lock
115056		1	Name plate
171308		4	Name plate screws
†164765		1	Volt-ohmmeter 0-150 v. a-c, 0-1000 ohms

*Sperry part number.

†Supplied only with sound locators having serial numbers below 376.

36. The following listed tools are supplied with each sound locator in addition to those accessories mentioned in the foregoing.

<i>F. A.</i>			
<i>Part*</i>	<i>Drawing</i>	<i>Number</i>	<i>Description</i>
<i>No.</i>	<i>No.</i>	<i>Required</i>	
158800		1	Wrench, double end ($\frac{1}{4}'' \times \frac{5}{16}''$)
158801		1	Wrench, double end ($\frac{3}{8}'' \times \frac{7}{16}''$)
156695		1	Wrench, double end ($\frac{1}{2}'' \times \frac{9}{16}''$)
165520		1	Wrench, end (adjustable)
154739	A-177656	1	Wrench, jack
165521		1	Hammer
35591		1	Pliers, side cutting
35592		1	Screwdriver ($4\frac{1}{2}''$)
4680		1	Screwdriver ($1\frac{1}{4}''$)
165509		1	Can, oil
165519	A-177753	1	Wrapper
153499		1	Lamp, portable trouble

*Sperry part number.

37. If any of the above listed equipment or tools are lost, or damaged beyond repair, replacements may be requisitioned.

NOTE: Information relative to spare parts, together with pertinent manufacturer's information, may be obtained by referring to TM 9-1660 and to the Manufacturer's Parts List.

SECTION VI

TRAINING OF PERSONNEL

I—GENERAL

1. In order that the sound locator may be operated most effectively, it is imperative that the listeners and corrector operators be chosen

not only for their aptitude in this work, but that they be thoroughly trained in the operation of the equipment, and continually exercised in the use of their binaural sense of direction and balance. It is with this in mind that the following method of choosing and training operators is outlined.

II—CHOOSING OPERATORS

2. The operators should be chosen by selecting from the entire battery personnel, if possible, the men who are best suited for this work from the standpoint of the following requirements:

- a. Desire to become a sound locator operator.
- b. Patience and attentiveness.
- c. Acuity of hearing. (Applicant should be questioned relative to any previous trouble with hearing and/or sight.)

3. Any previous education in mathematics and physics is not a pertinent requisite, but is desirable, for it will promote a better understanding of the sound locator theory and operation. Acuity of hearing, however, is the outstanding requirement for this type of work.

III—ELIMINATION EXAMINATIONS

4. The above requirements having been satisfactorily met, each man is then required to point out a movable sound source, concealed behind a screen or thin partition. This check should be followed by another in which the man is blindfolded and required to point out any one of three sound sources of different pitch, but approximately equal in intensity, which are separated by about 30° at the listener's position.

5. If the results obtained by these first two tests show that the man has a reasonably good binaural sense, he is then subjected to a test to determine his relative hearing ability. Each ear should be tested on an audiometer at all octaves included within the range of general audibility, and the results so obtained are compared with a normal ear. Men whose ears are poorly matched for aural acuity, over a range of from 60 to 4,000 cycles per second, should not be considered for further tests. Men whose ears are shown to be deficient in acuity by more than 5 decibels also should be eliminated from further consideration as listeners.

6. The men who have so far successfully passed all tests are then subjected to the following series of checks on a binaural training instrument.

- a. The students are given a brief demonstration of the training

SOUND LOCATOR M2

instrument, and allowed to operate the handwheels while listening.

b. A student is then blindfolded and seated at the instrument with the stethoscope in his ears. The instructor will offset the pointer with his handwheel, and the student will return the sound to what he considers to be the center, the accuracy of such centering, as indicated by the pointer, being recorded. A series of such centering tests is made for both the right and left offset.

c. After a rest interval, the student is then required to maintain the sound continuously binaurally centered, while the instructor simulates an aerial target by continuously moving his handwheel. The accuracy of "following" is recorded at approximately 10 second intervals.

IV—FIELD TRAINING

7. Consideration of the records thus far will determine fairly accurately as to which of the men are suitably equipped for this type of work. At least six men should be chosen for each sound locator, these men being divided into groups of three each, to provide two operating crews for each sound locator.

8. The men chosen to be listeners should then be given a considerable amount of training in crew groupings at the binaural training instrument indoors, and on the sound locator outdoors. Training on the sound locator should be concentrated at first, on centering the instrument on a sound source at the top of a high flagpole or a tree. A sound source on the top of a building is not satisfactory for this purpose, due to reflection and distortion of the sound wave.

9. The sound locator should be placed at a distance away from the sound source, so as to give an elevation angle of about 30° . Accuracy of centering can be checked by the corrector operator viewing the sound source in the open sight mirror. With the speed and parallax settings at zero, the sound source should appear in back of the pantograph pointer, if the instrument is accurately centered.

10. It is a good plan to have the qualified sound locator listeners trained to operate the corrector mechanism. In this manner the personnel complement of three men can be rotated at the three stations, namely (1) azimuth, (2) elevation, and (3) corrector. This will provide a break in the monotony of performing the same duty at all times. Such rotation of personnel assures that the men will be thoroughly familiar with the effect of ragged following on the part of the listeners, as related to the quality and accuracy of the corrections obtainable, and the resultant transmitted data. For a description of the effect of ragged following and instructions for proper operation, see "Tracking a Target" in section IV.

APPENDIX A
REFERENCES

1. Standard nomenclature lists:

Until SNL F-176, Sound Locator M2, becomes available, the Manufacturer's Parts List will be used.

An up-to-date list of SNL's is maintained as the "Ordnance Publications for Supply Index"----- (OPSI).

2. Technical manuals:

3-inch AA gun matériel-----	TM 9-360.
Cleaning and preserving materials-----	TM 9-850.
Ordnance maintenance, sound locator M2-----	TM 9-1660.

APPENDIX B

COMPUTATION OF CORRECTIONS

I—GENERAL

1. Section II of the text contains a general description of how the sound locator operates, and how mechanical corrections within it are made for several errors inherent in this aural method of directing a searchlight at an airplane target. In this appendix these errors are stated in mathematical language, and equations are developed for use in calculating the required corrections.

II—SOUND LAG CORRECTION

2. The mathematical derivation of change of azimuth motion with respect to change of elevation motion of the horns, in tracking a target, shows that at any instant:

$$\frac{\Sigma a}{\Sigma e} = \tan \alpha \left(\frac{1}{\cos E' \sin E'} \right)$$

where

$\frac{\Sigma a}{\Sigma e}$ = The instantaneous rate of change of the horns in azimuth with respect to their rate of change in elevation.

= Instantaneous angle between the horizontal projection of the target course and the horizontal projection of the line from the sound locator to the apparent target position (angle of approach).

E' = Instantaneous elevation angle of horns to the apparent target position.

3. Referring to figures 3, 4, and 5, the elevation and azimuth rollers are at right angles to each other and jointly give a composite motion to the resolving ball, which determines its plane of rotation and also the direction in which the course indicator (model airplane) points. The elevation roller is mounted on the side toward the target, so that this roller always is in the vertical plane of direction from the sound locator to the apparent target position. Therefore, to give true course indication, the longitudinal axis of the model airplane should make an angle DOF (fig. 5) with the azimuth heading of the horns, equal to the actual target course angle. For a true course indication the tangent of angle DOF should, at all times, equal $\tan \alpha$, where α is the course angle of the target. But the tangent of angle DOF equals $\frac{\Sigma a}{\Sigma e}$, so that $\frac{\Sigma a}{\Sigma e}$ must equal $\tan \alpha$.

4. However, from the derivation of the horn movement, $\frac{\Sigma a}{\Sigma e} = \tan \alpha$ $\left(\frac{1}{\cos E' \sin E'} \right)$, which indicates that the only time that $\frac{\Sigma a}{\Sigma e}$ of the horns is equal to $\tan \alpha$, is when $\frac{1}{\cos E' \sin E'}$ is unity. This is never the case, since the maximum value of the product $\cos E' \sin E'$ is 0.5. To get a true indication, the azimuth movement of the horns should be multiplied, at all times, by $\cos E' \sin E'$. Thus the final motion applied to the ball would be such that $\frac{\Sigma a}{\Sigma e} = \tan \alpha$. Actually instead of decreasing azimuth horn motion, as applied to the resolving ball, by the factor $\cos E' \sin E'$ the ratio of the *elevation* gearing is increased by an average value of the factor $\cos E' \sin E'$. Thus, the elevation gearing as applied to the resolving ball has a ratio of 2.5 times that of the azimuth gearing. The optimum operation range of the sound locator is between 15° and 75° elevation. Between these limits, $\cos E' \sin E'$ varies from .25 to .50 and small error is introduced by taking an average constant value of .4 for this factor. Consider that the movement of the horns in azimuth and elevation in tracking a target is such that $\frac{\Sigma a}{\Sigma e} = \tan \alpha \frac{1}{0.4}$. Then to keep $\frac{\Sigma a}{\Sigma e} = \tan \alpha$ at all times, the elevation of the horns must be increased by $\frac{1}{0.4}$ or 2.5, before it is applied to the ball analyzer. Then $\frac{\Sigma a}{\Sigma e} = \tan \alpha \frac{1}{0.4 \times 2.5} = \tan \alpha$. The action of the ball analyzer, with respect to the pantograph structure as well as to target course, is schematically shown in figure 5.

5. As explained previously, the triangle OAB set up in the instrument, figure 9, is similar to the space triangle. These triangles being in the same slant plane, their horizontal and vertical projections will also be similar. Figure 20 illustrates the horizontal projections, the subscripts "h" denoting the horizontal projections of the vertex points of the triangles.

6. Therefore, triangle OA_hB_h is similar to OT_hT_{oh} and it is possible to solve for the azimuth correction angle " δ_x " in terms of either triangle. In the following equations, the model triangle OA_hB_h is used. Line A_hC_h is drawn perpendicular to line OB_h ,

Then

$$\begin{aligned} \tan \delta_x &= \frac{A_hC_h}{7.5 \cos E' - B_hC_h} \\ \frac{A_hC_h}{S} &= \sin \alpha, \text{ or, } A_hC_h = S \sin \alpha \\ \frac{B_hC_h}{S} &= \cos \alpha, \text{ or, } B_hC_h = S \cos \alpha \end{aligned}$$

SOUND LOCATOR M2

Therefore,

$$\tan \delta_z = \frac{S \sin \alpha}{7.5 \cos E' - S \cos \alpha}$$

$$\delta_z = \tan^{-1} \frac{S \sin \alpha}{7.5 \cos E' - S \cos \alpha} \quad (A)$$

This is the equation for determining the azimuth correction to be applied to the sight mirror, to sight along the line OA_hT_{oh} .

7. Although the sound locator horns are pointed at the apparent position of the target, the insertion of estimated target speed corrects

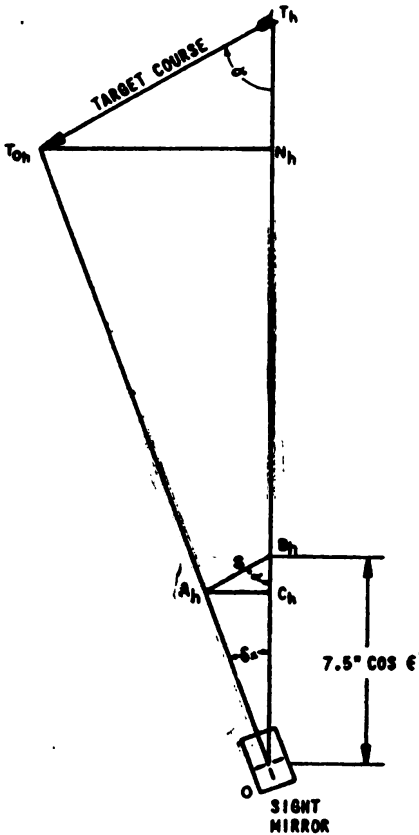


FIGURE 20.—SOUND LAG PROBLEM
(Horizontal view)

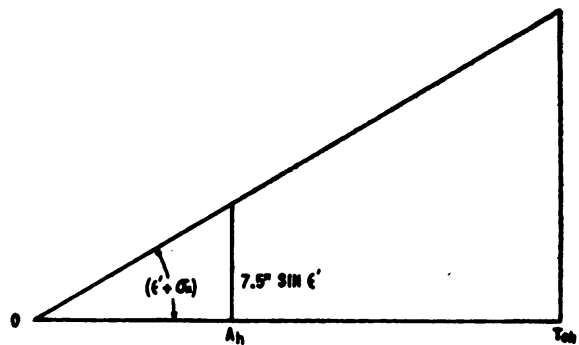


FIGURE 21.—SOUND LAG PROBLEM
(Elevation view)

the position of the pantograph pointer for sound lag in both azimuth and elevation, with the result that its position coincides with the line of sight to the actual target position. The pantograph's motion in following the target's motion automatically inserts the trigonometric functions of angles involved, maintaining true line-of-sight position.

8. Figure 21 represents a normal view of the vertical plane intersecting the horizontal plane in figure 20. In these figures,

$$\frac{A_hC_h}{OA_h} = \sin \delta_z \text{ or, } OA_h = \frac{A_hC_h}{\sin \delta_z} = \frac{S \sin \alpha}{\sin \delta_z}$$

and
$$\tan (E' + \sigma_z) = \frac{7.5 \sin E'}{OA_h}$$

$$\begin{aligned}\text{Therefore, } \tan (E' + \sigma_x) &= \frac{7.5 \sin E'}{\frac{S \sin \alpha}{\sin \delta_x}} \\ &= \frac{7.5 \sin E' \sin \delta_x}{S \sin \alpha}\end{aligned}\quad (\text{B})$$

9. When the target is flying at a course angle of 0° or 180° , i. e., along the line OT_h , figure 20, toward or away from the sound locator, σ_x equals zero and formula (B) becomes indeterminate. Referring to figure 22,

$$\tan (E' + \sigma_x) = \frac{7.5 \sin E'}{7.5 \cos E' + S} \text{ when } \alpha = 180^\circ \quad (\text{C})$$

$$\text{and} \quad \tan (E' + \sigma_x) = \frac{7.5 \sin E'}{7.5 \cos E' - S} \text{ when } \alpha = 0^\circ \quad (\text{D})$$

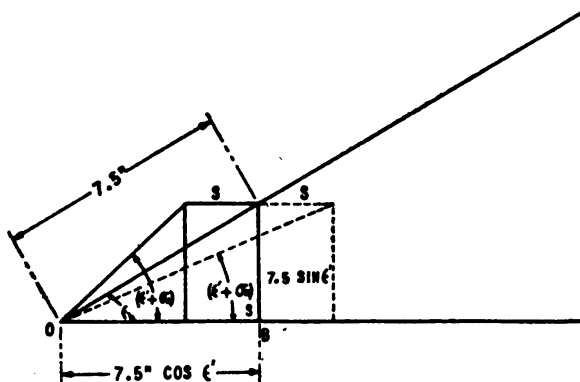


FIGURE 22.—SOUND LAG PROBLEM (Elevation view).

10. When α is equal to zero (the target is approaching a point directly over the sound locator) there will be a point beyond which the target is in such a position that the elevation correction for sound lag will cause the line of sight to have more than a 90° elevation from the original zero reference line.

11. The searchlight movement in elevation is restricted to approximately 1775 mils so that before this point is reached it would be turned 180° in azimuth in normal operation. Formula (A) however, does not indicate an azimuth correction of 180° . Formula (D) does however, indicate the necessary 180° correction in azimuth by a change of sign and by giving a solution, not for the angle $(E' + \sigma_x)$ but for its supplementary angle $180^\circ - (E' + \sigma_x)$, which is the correct elevation of the target's actual position with respect to the sound locator after it has been turned 180° in azimuth from its initial heading. For normal operating conditions the formula derived are valid and in the field the correct operation for the above discussed condition would be obvious.

SOUND LOCATOR M2

12. It is possible to derive a general formula for $\tan (E' + \sigma_x)$ that is determinate for all conditions. It is:

$$\tan (E' + \sigma_x) = \frac{7.5 \sin E'}{\sqrt{(7.5 \cos E')^2 - 2(7.5 \cos E') S \cos \alpha + S^2}} \quad (\text{E})$$

13. When $\alpha = 0^\circ$ in equation (E) it serves to reduce it to operation (D) and, when $\alpha = 180^\circ$ in equation (E) it serves to reduce it to equation (C) as shown in the following:

When

$$\alpha = 0^\circ$$

then

$$\begin{aligned} \tan (E' + \sigma_x) &= \frac{7.5 \sin E'}{\sqrt{(7.5 \cos E')^2 - 2(7.5 \cos E') S(1) + S^2}} \\ &= \frac{7.5 \sin E'}{7.5 \cos E' - S} \end{aligned} \quad (\text{D})$$

and when

$$\alpha = 180^\circ$$

then

$$\begin{aligned} \tan (E' + \sigma_x) &= \frac{7.5 \sin E'}{\sqrt{(7.5 \cos E')^2 - 2(7.5 \cos E') S(-1) + S^2}} \\ &= \frac{7.5 \cos E'}{\sqrt{(7.5 \cos E')^2 + 2(7.5 \cos E') S + S^2}} \\ &= \frac{7.5 \cos E'}{7.5 \cos E' + S} \end{aligned} \quad (\text{C})$$

14. Although equation (E) is applicable under all conditions and does not depend upon the solution of δ_x first to evaluate $\tan (E' + \delta_x)$, it is more cumbersome for use in calculations. Therefore, equation (B) is usually used because of its simplicity. For the two cases in which equation (B) becomes indeterminate (when $\alpha = 0^\circ$ or 180°) equations (C) and (D) are used.

15. A typical problem for sound lag computation is outlined in the following, to illustrate the foregoing mathematical derivations and equations:

Assume the following conditions:

Target speed = 400 mph (scale model correction: $S = 4$ inches).

Elevation angle (E') = 45° = 800 mils (to apparent target position).

Target course angle (α) = 80 mils.

16. The distance from the center of the sight mirror to the center of the pantograph ball is 7.5 inches and the line determined by these two points is at an angle of 45° , or 800 mils, with respect to the horizontal plane (0°). Therefore, solving for azimuth correction angle (δ_x), to be applied for sound lag, it is found that:

$$\delta_x = \tan^{-1} \frac{S \sin \alpha}{7.5 \cos E' - S \cos \alpha} \quad (A)$$

Substituting,

$$\begin{aligned} \delta_x &= \tan^{-1} \frac{4 \sin 800}{7.5 \cos 800 - 4 \cos 800} \\ &= \tan^{-1} \frac{4 \times 0.707}{7.5 \times 0.707 - 4 \times 0.707} \\ \delta_x &= \tan^{-1} \frac{4}{7.5 - 4} = \tan^{-1} \frac{4}{3.5} = \tan^{-1} 1.143 \end{aligned}$$

therefore,

$$\delta_x = 868 \text{ mils}$$

Solving for the elevation correction angle, (E) it is found that;

$$\begin{aligned} \tan (E' + \sigma_x) &= \frac{7.5 \sin E' \sin \delta_x}{S \sin \alpha} \\ &= \frac{7.5 \sin 800 \sin 868}{4 \sin 800} \\ &= \frac{7.5 \times 0.707 \times 0.753}{4 \times 0.707} = 1.412 \end{aligned} \quad (B)$$

Therefore,

$$E' + \sigma_x = \tan^{-1} 1.412 = 972 \text{ mils}$$

Since

$$E' = 800 \text{ mils}$$

Then

$$\sigma_x = (E' + \sigma_x) - E' = 972 - 800 = 172 \text{ mils}$$

III—PARALLAX CORRECTION

17. The method of determining parallax offset corrections for base lines of 200 to 1,000 feet and slant ranges of 5,000 to 30,000 feet is explained in the following paragraphs. Referring to figure 23 (A), the sound locator sight mirror center is shown at point *O*, the searchlight as point *L*, the base line $OL = 900$ feet, the apparent slant range $OT = 7,250$ feet

SOUND LOCATOR M2

Therefore, the correction angle

$$= MLT = \tan^{-1} \frac{900}{7,250} = \tan^{-1} 0.1242$$

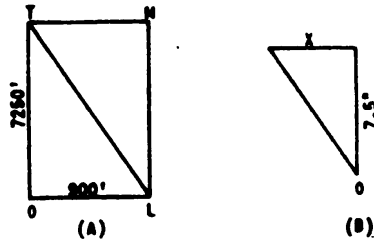


FIGURE 23.—PARALLAX CORRECTION ANGLE PRINCIPLE.

18. To turn the sight mirror through the same angle, the amount of pantograph ball displacement must be determined as follows:

Refer to figure 23 (B)

X = offset distance.

7.5'' = distance between center of sight mirror and center of pantograph ball with zero correction.

Therefore,

$$\frac{X}{7.5} = 0.1242$$

Transposing,

$$X = 7.5 \times 0.1242 = 0.932 \text{ inch}$$

A setting of 10 on the parallax offset scale corresponds to 0.932 inch.

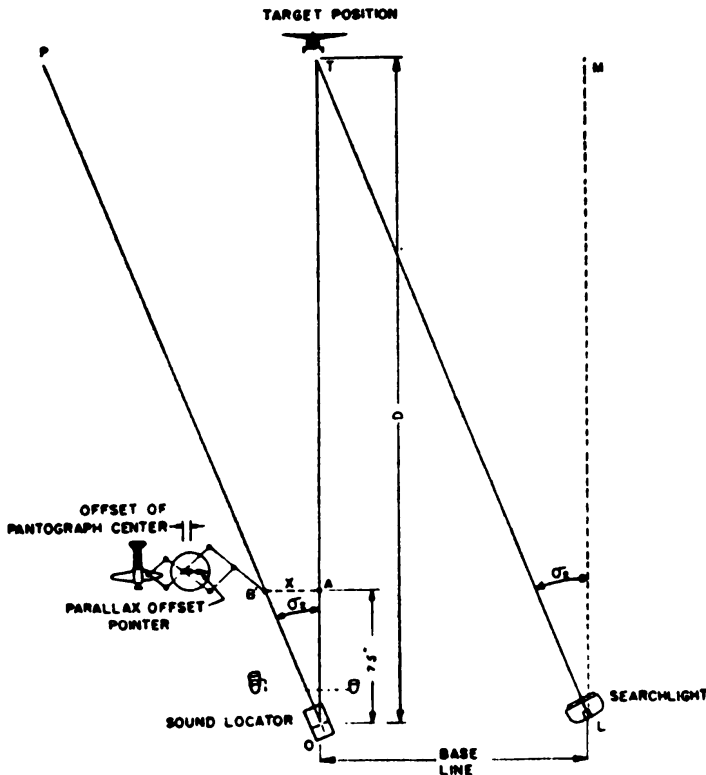


FIGURE 24.—TYPICAL PARALLAX PROBLEM.

19. If the target is at some other slant range, say 18,000 feet, then, in figure 23 (A),

$$OT = 18,000 \text{ feet}$$

and correction angle

$$= MLT$$

$$= \tan^{-1} \frac{900}{18,000}$$

$$= \tan^{-1} 0.0500$$

Therefore, the angular displacement of the sight mirror, as related to pantograph ball offset, is then

$$\frac{X}{7.5} = 0.0500$$

and, transposing,

$$X = 7.5 \times 0.0500$$

$$= 0.3750 \text{ inch}$$

20. The maximum offset obtainable in the corrector mechanism is 0.932. This has been divided into ten divisions on the offset scale, each division equal to $\frac{0.932}{10}$ or 0.0932 inch. An offset setting then, of 0.3750 inch corresponds to an offset scale setting of $\frac{0.3750}{0.0932} = 4$ (approximately). This is given by the parallax correction graph for a slant range of 18,000 feet with a 900-foot base line.

IV—COMBINED SOUND LAG AND PARALLAX CORRECTION

21. The action of a target, with respect to a sound locator and searchlight operating together at a displacement distance of OL , is illustrated in figure 25. The sound locator is at point O and the searchlight at point L .

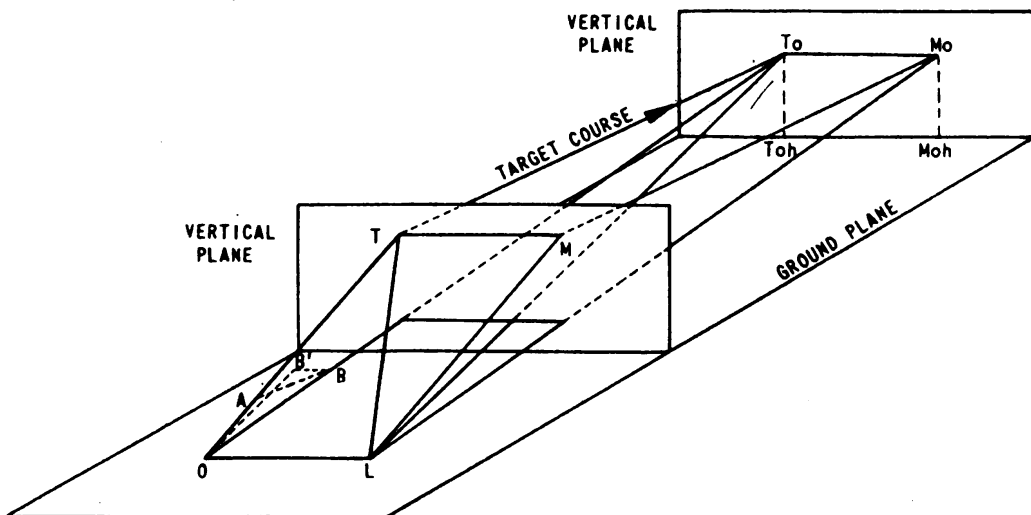


FIGURE 25.—SOUND LAG AND PARALLAX COMBINED.

SOUND LOCATOR M2

22. When the sound locator "picks up" the target sound, it will indicate the target as being at point T . The apparent slant range is OT , at some angle of elevation with respect to the ground plane. Without parallax correction, the searchlight beam is directed along the line LM . Since the data transmission system causes the searchlight beam to assume the same azimuth heading and elevation angle as the line OT , then $OLMT$ represents a section of a slant plane.

23. The line OA from the sight mirror center to the center of the pantograph ball lies along the line OT . It is in the same slant and at the same elevation angle, with respect to the ground plane. In the apparent target position T , the *apparent* parallax correction angle required is MLT . An angular correction of the searchlight beam must be made so that the result of such correction would be to move the beam LM through the angle MLT , in the slant plane $OLMT$.

24. However, the target will have advanced to point T_0 along its course TT_0 . With the target speed correction inserted, the line of sight OT_0 and the searchlight beam, LM_0 , will form a new slant plane section, OLM_0T_0 at a different elevation angle with respect to the ground plane. The actual parallax correction angle now required is M_0LT_0 . Assuming actual values for solution of this problem, the following procedure is observed.

OT = Apparent slant range from sound locator = 7,250 feet = 7.5 inches as reduced to scale of corrector model.

S = Target speed along $T'T$ = 400 mph = 4 inches as reduced to scale of corrector model.

α = Target course angle = 225° = 4,000 mils.

E' = Elevation of apparent slant range OT = 45° = 800 mils.

OL = base line = 900 feet.

25. In the solution of this problem the corrections for sound lag and for parallax are found by geometrical analysis of the figure shown in figure 25. The results are reduced to the dimensions of the model triangle OAB , figure 9, and the required setting in inches of the parallax offset mechanism is calculated. Parallax settings for all slant ranges and base lines within the scope of the sound locator are included in the family of curves of figure 30.

26. The target is assumed to be moving at a constant speed and constant altitude. TT_0M_0M , therefore represent a section of a plane that is horizontal with the ground plane.

27. If the parallax correction graph is based on the apparent slant range OT , and the target is at another point in space, the actual slant range OT_0 , of the target may be greater or less than OT , depending on the course of the target. It is necessary first to determine the

actual slant range and then determine whether or not the parallax correction inserted for an apparent slant range of 7,250 feet is satisfactory for actual slant range.

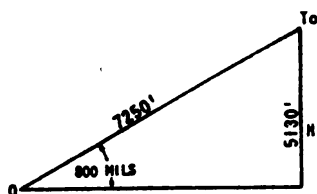


FIGURE 26.—ALTITUDE DETERMINATION PRINCIPLE.

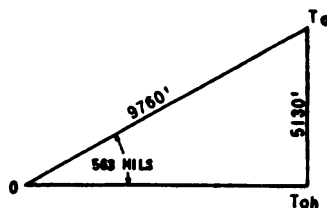


FIGURE 27.—SLANT RANGE DETERMINATION PRINCIPLE.

28. The smaller the slant range and the greater the target speed, the greater will be the deviation of the actual slant range from the apparent slant range. Therefore, this problem has as its assumed conditions the maximum target speed and a small value of slant range.

29. The apparent slant range OT is at 45° , or 800 mils, above the horizontal or ground plane. The altitude of the target above the ground plane can be found when the slant range is known. Referring to figure 26,

$$\frac{H}{7,250} = \sin 800$$

$$\text{or, } H = 7,250 \times 0.707 = 5,130 \text{ feet}$$

30. The elevation of the actual slant range vector (angle T_0OT_{0h} , fig. 25) can be determined by the general formula:

$$\begin{aligned} \tan (E' + \sigma_x) &= \frac{7.5 \sin E'}{\sqrt{(7.5 \cos E')^2 - 2(7.5 \cos E')S \cos \alpha + S^2}} \\ &= \frac{7.5 \sin 800}{\sqrt{(7.5 \cos 800)^2 - 2(7.5 \cos 800) 4 \cos 4000 + (4)^2}} \\ &= \frac{7.5 \times .707}{\sqrt{(7.5 \times 0.707)^2 - 2(7.5 \times 0.707) 4(-\cos 800) + (4)^2}} \\ &= \frac{5.3}{\sqrt{28.1 + 30 + 16}} \\ &= \frac{5.3}{\sqrt{74.1}} = \frac{5.3}{8.6} = 0.6160 \end{aligned} \quad (E)$$

Therefore, $(E' + \sigma_x) = \text{elevation angle} = \tan^{-1} 0.6160 = 563 \text{ mils}$

31. Referring to figure 27, it becomes possible to determine the actual slant range, knowing the target height and the angle of elevation, in the following manner:

SOUND LOCATOR M2

$$\frac{5130}{OT_0} = \sin 563$$

$$\text{or, } OT_0 = \frac{5,130}{\sin 563} = \frac{5,130}{0.525}$$

$$\text{and, } OT_0 = 9,760 \text{ feet}$$

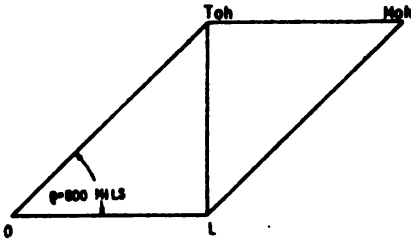


FIGURE 28.—SLANT PLANE
(Horizontal projection).

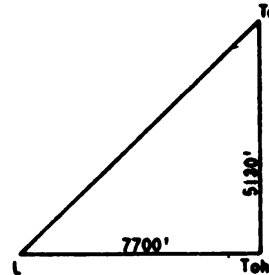


FIGURE 29.—ACTUAL SLANT
RANGE DETERMINATION.

32. Having the slant range, and its elevation with respect to the ground plane, the slant plane OLM_0T_0 , figure 25, should be viewed from above, so that its horizontal projection would be as shown in figure 28. Points T_{0h} and M_{0h} , figure 25, are projections of points T_0 and M_0 on the horizontal, or ground plane.

33. Assuming that the target started at such a point that its actual position causes angle β figure 28, to be 45° or 800 mils with respect to the base line OL , it becomes possible to solve for $T_{0h}L$. Since OT_{0h} in figure 28 is identical with OT_{0h} in figure 27,

Then

$$\begin{aligned} OT_{0h} &= 9,760 \cos 563 \\ &= 9,760 \times 0.851 = 8,310 \text{ feet} \end{aligned}$$

and

$$\begin{aligned} (T_{0h}L)^2 &= (OT_{0h})^2 + (OL)^2 - 2(OT_{0h}) \times OL \cos 800 \\ &= 8,310^2 + 900^2 - 2 \times 8,310 \times 900 \times 0.707 \\ (T_{0h}L)^2 &= 6,910 \times 10^4 + 81 \times 10^4 - 1,060 \times 10^4 = 5,931 \times 10^4 \end{aligned}$$

Then

$$T_{0h}L = 7,700 \text{ feet}$$

34. Therefore, in the slant plane OLM_0T_0 , figure 25, the length of the slant range LT_0 , as shown in figures 25 and 29, from the target to the searchlight, may be determined as follows:

$$\begin{aligned} (LT_0)^2 &= 7,700^2 + 5,130^2 \\ &= 5,930 \times 10^4 + 2,610 \times 10^4 \end{aligned}$$

and,

$$LT_0 = 9,240 \text{ feet}$$

35. The correction angle M_0LT_0 , in the slant plane OLM_0T_0 , figure 25, may then be determined by the following method. Since OLM_0T_0 is a parallelogram, M_0L is equal to OT_0 , and is equal to 9,760 feet.

Therefore

$$(T_0M_0)^2 = (LT_0)^2 + (M_0L)^2 - 2 \times LT_0 \times M_0L \cos (\text{angle } M_0LT_0)$$

$$\cos (\text{angle } M_0LT_0) = \frac{9,240^2 + 9,760^2 - 900^2}{2 \times 9,240 \times 9,760} = 0.9960$$

$$\text{angle } M_0LT_0 = \cos^{-1} 0.9960 = 91 \text{ mils}$$

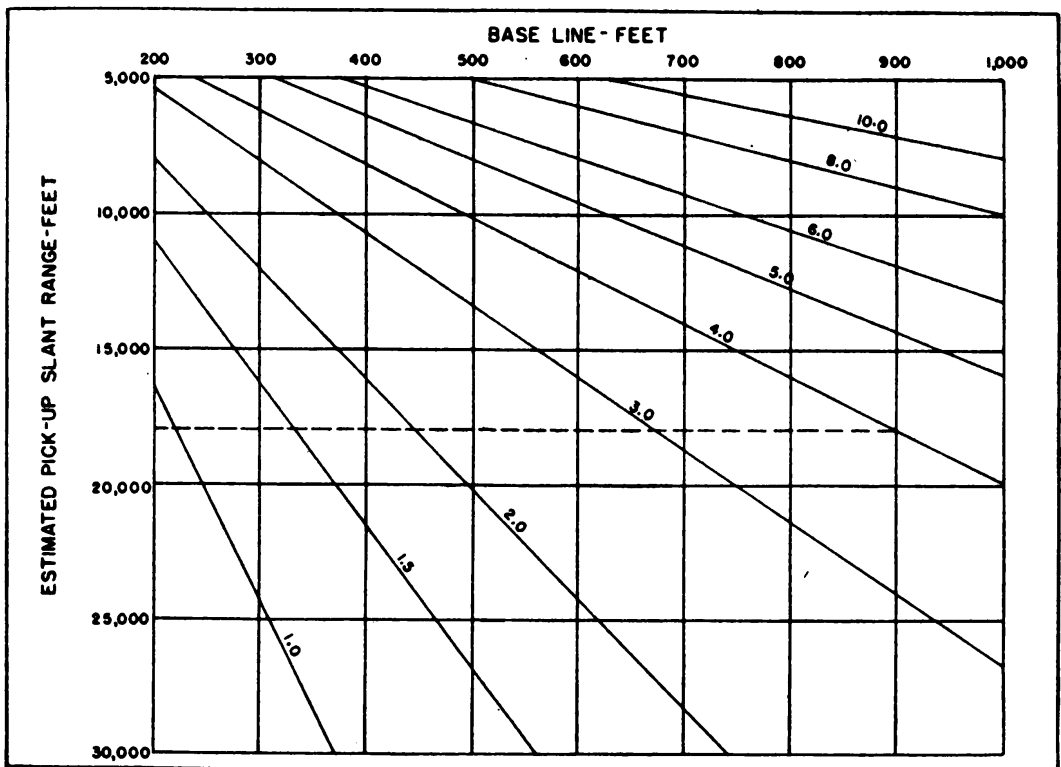


FIGURE 30.—GRAPH OF PARALLAX SETTINGS (Numbers on slanting lines are arbitrary units marked on instrument parallax offset scale).

36. Therefore, 91 mils is the correction angle to be applied to the searchlight in the slant plane OLM_0T_0 to cause the beam to strike the target. The parallax offset of the pantograph ball should apply this same angular correction in the same slant plane. For an apparent slant range of 7,250 feet, from the target to sound locator, the offset graph, figure 30, shows that the offset should be put at 10 on the scale. This corresponds to a movement of the pantograph ball, parallel to the base line, of 0.932 inches and it is put in with the pantograph ball at the position of sound lag correction.

37. Referring to the small scale portion of figure 25, representing the model triangle in the corrector mechanism, A is the apparent ball position with respect to the center of the sight mirror point O . The line OA then = 7.5 inches. For a target speed of 400 mph, the ball would be moved along AB parallel with the target course TT_0 , a distance of 4 inches. OA is along the line OT and is at the same elevation angle with respect to the ground plane, or 800 mils.

38. For the assumed course angle of 225° and a target speed of 400 mph, it is possible to solve for the elevation correction angle to be applied to the pantograph ball to correct for sound lag as follows:

$$\begin{aligned}(E' + \sigma_z) &= \tan^{-1} \frac{7.5 \sin E \sin \delta_z}{S \sin \alpha} \\ &= \tan^{-1} \frac{7.5 \sin 800 \sin 341}{4 \sin 4,000} \\ &= \tan^{-1} \frac{7.5 \sin 800 \sin 341}{4 \sin 800} \\ &= \tan^{-1} \frac{7.5 \times 0.707 \times 0.328}{4 \times 0.707} = 0.6150\end{aligned}$$

then $(E' + \sigma_z) = \tan^{-1} 0.6150 = 563$ mils

39. As shown in figure 25, the two sides OA and AB of the model triangle are always proportional to the two sides, OT and TT_0 , of the space triangle. Therefore, the third side of the model triangle, OB , must be proportional to the third side, OT_0 , of the space triangle.

Therefore,
$$\frac{OA}{OT} = \frac{OB}{OT_0} \text{ or, } OB = \frac{OA \times OT_0}{OT}$$
$$OB = 7.5 \times \frac{9,760}{7,250} = 10.1$$

The elevation angle of OB , with respect to the ground plane is 563 mils, or the same as the elevation angle of OT_0 .

40. The pantograph ball is moved from B to a point B' , so that BB' is parallel to the base line OL . A line OB' is drawn from the center of the sight mirror to the new position of the pantograph ball, forming a new triangle OBB' . If the necessary condition that the angle BOB' equal the parallax correction angle M_0LT_0 is imposed, then triangle OBB' must be similar to triangle M_0LT_0 , for the three sides of triangle OBB' are parallel to the three sides of triangle M_0LT_0 .

41. It becomes possible then, to solve for a value BB' in the corrector mechanism that will result in angle BOB' equalling angle M_0LT_0 , as follows:

$$\frac{BB'}{OB} = \frac{M_0T_0}{LM_0} \text{ or, } BB' = OB \times \frac{M_0T_0}{LM_0}$$

$$\text{and, } BB' = 10.1 \times \frac{900}{9,760} = 0.932 \text{ inch}$$

42. However, 0.932 inch corresponds to a setting of 10 on the offset scale and this is the setting indicated by the parallax correction graph for an apparent slant range of 7,250 feet.

43. Therefore, there is no error involved in setting in the parallax correction as given for an apparent slant range, when the pantograph ball is at the actual slant range (i. e., corrected for sound lag). This is due to the fact that the distance from the center of the sight mirror to the pantograph ball increases in proportion to the amount of parallax originally set in for the apparent slant range in exactly the same manner in which the distance from the searchlight to point T_0 , figure 25, increases in proportion to the base line distance, OL .

APPENDIX C **INSPECTION REPORT** **SOUND LOCATOR M2**

Serial No. _____ Date _____

Contract No. _____ Inspector _____

Sound locator equipment (complete shipment) as per Drawing No. 644844 (644127†) consists of the following:	Remarks
1. Sound locator proper, as per drawing No. 644845 (644128†), consists of the following: a. Corrector as per drawing No. 644846 (644129†), Serial No. _____ b. Column as per drawing No. 642605, Serial No. _____ c. Platform as per drawing No. 644175, Serial No. _____ d. Double horn arm assembly, as per drawing No. 76299, Serial No. _____ e. Single horn arm assembly, as per drawing No. 76298, Serial No. _____ f. Helmets (2), as per drawing No. 643904 g. Check for installation of two a-c synchronous repeaters as per drawing No. 76226 (*C44968) Elevation repeater Serial No. _____ Azimuth repeater Serial No. _____ 2. Cable assembly, as per drawing No. 800686, consists of the following: a. Sound locator cables (2) as per drawing No. 166421 b. Male plugs (2) as per drawing No. 643756 (*C56029) c. Female plugs (2) as per drawing No. 643757 (*C56030) 3. Cable reel with cranks (2) as per drawing No. 643939, Serial No. _____ 4. Stowage box as per drawing No. 644357, including contents as per drawing No. 800689, containing the following items: a. Tools and wrapper assembly as per drawing No. 165522 b. Jack wrench assembly as per drawing No. 154739 c. Tube clamp kit as per drawing No. 156180 d. Four (4) helmet tubes as per drawing No. 800488 or 801415 e. Four (4) helmets with bushings assembled (1) Two (2) helmets as per drawing No. 643904 (same as listed under item 1f) (2) Two (2) helmets as per drawing No. 643940 (3) Eight (8) helmet bushing assemblies as per drawing No. 165840 (assembled in helmets) f. One corrector assembly with pantograph removed same as Item 1a g. Pantograph in box as per drawing No. 800689 h. One sight cover (moleskin cloth) as per drawing No. 89415 i. One corrector assembly cover (canvas) as per drawing No. 75636 j. One pantograph drive cover (moleskin cloth) as per drawing No. 89414 k. One transportation bracket assembly, as per drawing No. 76334 l. Spare parts in box as per drawing No. 167121 m. One trouble lamp as per drawing No. 153499	

*These are Frankford Arsenal numbers. Repeaters in this case are used as transmitters.

†For sound locators with serial numbers below 376.

INSTRUCTION GUIDE

Sound locator equipment (complete shipment) as per Drawing No. 644844 (644127†) consists of the following:	Remarks
4. Stowage box as per drawing No. 644357—Continued. †n. One volt-ohmmeter in leather carrying case as per drawing No. 164765 o. Two padlocks and keys as per Drawing No. 153439 (attached to stowage box) 5. Three (3) horn caps as per drawing No. 800687 6. Three (3) horn covers (canvas) as per drawing No. 89413 7. Two instruction books 8. Inspection report † For sound locators with serial numbers below 376.	

Test No.	Test	Remarks
1	<i>Leveling.</i> —Level the sound locator carefully on its base. At no position throughout a 6,400-mil traverse should the level indicate an error exceeding $\pm 1/2^\circ$	
2	<i>Operation of leveling jack screws.</i> —The leveling screws should move freely and without seizing	
3	<i>Gear trains.</i> — a. Azimuth handwheel for complete traverse and movement through 6,400 mils. Check locking clutch b. Elevation handwheel for complete traverse and movement through 1,600 mils. Stops for limits of 0 mils and 1,600 mils. Check elevation locks c. Manual movement of horns in azimuth through 6,400 mils (both directions) d. Manual movement of horns in elevation through 1,600 mils (both directions)	
4	<i>Corrector knob (freedom of movement).</i> —Rotate on both vertical and horizontal axes	
5	<i>Air speed setting screw.</i> —For operation and full movement of scale 0 to 400 mph	
6	<i>Parallax cam.</i> —For full movement of scale setting numbers 0 to 10. Check locking nut	
7	<i>Declutching gear.</i> —For engaging and disengaging	
8	<i>Parallax pointer.</i> —For freedom of movement throughout one complete rotation	
9	<i>Pantograph accuracy.</i> — a. Check for backlash and lost motion which should not exceed $\pm 1/2^\circ$ ball pointer diameter b. Check for fitting on mount c. Set air speed, parallax, and corrector at zero. (The ball pointer should now be centered on mirror cross lines). For full movement in elevation, ball pointer should not be displaced more than $\pm 1/2$ diameter of ball pointer d. For full movement in azimuth, the displacement should not exceed $\pm 1/2$ diameter of ball pointer	
10	<i>Column and horn assembling studs.</i> —Check for ease of movement and clamping	
11	<i>Course indicator.</i> — a. Elevation check: - Rotate horns in elevation until course indicator has assumed a fixed position. Course indicator shall be at right angles to elevate axis within $\pm 2^\circ$ b. Azimuth check: - Rotate horns in azimuth until course indicator has assumed a fixed position. Course indicator shall be parallel to elevation axis within $\pm 2^\circ$	

SOUND LOCATOR M2

Test No.	Test	Remarks
	<i>Course indicator—Continued.</i>	
	<i>c. Component course check:</i> Rotate elevation and azimuth handwheels to drive ball analyzer drive rollers at equal speeds until course indicator assumes a fixed position which shall be $45^{\circ} \pm 2^{\circ}$	
12	<i>Corrector check.</i> —Check for maximum correction (using air speed and parallax). Mirror should be used for centering	
13	<i>Check of azimuth and elevation scales.—</i> <i>a. Graduations</i> <i>b. Azimuth scale for freedom of rotation</i> <i>c. Locking of azimuth scale</i>	
14	<i>Helmet tubes.—</i> <i>a. For clamping</i> <i>b. For snap fit with helmet bushing</i>	
15	<i>Transmitter drive.</i> —For backlash	
16	<i>Check "0" elevation of horns.—</i> <i>a. Check horns for "0" elevation using plumb bob</i> <i>b. When "0" position is obtained, corrector line of sight must be horizontal within $\pm \frac{1}{2}^{\circ}$</i>	
17	<i>Megohmmeter insulation test.</i> —Insulation resistance between terminals $E_1, E_2, E_3, P_1, P_2, A_1, A_2, A_3$, and corrector case shall not be less than 3 megohms	
18	<i>Continuity check.</i> —(Use ohmmeter or buzzer.) On terminal block, connect to terminals 11 and 13 with switch "out." Complete circuit should result	
19	<i>Acoustic check of azimuth horns.</i> —Acoustic center line of azimuth horns must be parallel with corrector line of sight within $\pm \frac{1}{2}^{\circ}$	
20	<i>Data transmission accuracy.—</i>	

AZIMUTH CHECK

Sound locator scale (mils)	C. W. dummy searchlight read (mils)	C. W. error	C. C. W. dummy searchlight read (mils)	C. C. W. error	Spread
00	-----	-----	-----	-----	-----
800	-----	-----	-----	-----	-----
1600	-----	-----	-----	-----	-----
2400	-----	-----	-----	-----	-----
3200	-----	-----	-----	-----	-----
4000	-----	-----	-----	-----	-----
4800	-----	-----	-----	-----	-----
5600	-----	-----	-----	-----	-----
6400	-----	-----	-----	-----	-----

ELEVATION CHECK

Sound locator scale (mils)	C. W. dummy searchlight read (mils)	C. W. error	C. C. W. dummy searchlight read (mils)	C. C. W. error	Spread
0	-----	-----	-----	-----	-----
400	-----	-----	-----	-----	-----
800	-----	-----	-----	-----	-----
1200	-----	-----	-----	-----	-----
1600	-----	-----	-----	-----	-----

INSTRUCTION GUIDE

Test No. 21. *Problem check of corrector.*—Pantograph pointer should be centered in mirror within $\pm\frac{1}{4}$ ball-pointer diameter. All angular settings and readings are in mills. Speed is in miles per hour.

Horns		Course indicator		Sound lag. corrections		Parallax corrections ¹				Searchlight heading		Position of ball pointer	Remarks
Elevation angle	Azimuth angle	Target speed	Course angle ¹	Azimuth angle	Elevation angle	Setting number	Direction of arrow	Azimuth angle	Elevation angle	Azimuth angle	Elevation angle		
1333	0	100	4800	+484	-31	0	-----	-----	-----	484	1302	-----	
1333	0	200	4800	+815	-107	0	-----	-----	-----	815	1226	-----	
1333	0	300	4800	+1015	-200	0	-----	-----	-----	1015	1133	-----	
1068	0	400	800	-1279	+94	0	-----	-----	-----	5121	1162	-----	
533	0	400	2400	-300	-159	0	-----	-----	-----	6100	374	-----	
1600	0	400	3200	0	-499	0	-----	-----	-----	0	1101	-----	
800	0	400	0	0	+555	10	Front.....	0	+174	0	1529	-----	
1333	0	400	4800	+1140	-294	10	Left.....	+78	-82	1218	957	-----	
1333	0	400	4800	+1140	-294	8	Left.....	+64	-66	1204	973	-----	
1333	0	400	4800	+1140	-294	6	Left.....	+50	-50	1190	989	-----	
1333	0	400	4800	+1140	-294	4	Left.....	+34	-34	1174	1005	-----	
1333	0	400	4800	+1140	-294	2	Left.....	+18	-17	1158	1022	-----	

¹ Course angle is measured clockwise with course angle of approaching target as zero angle.

² Parallax correction angle, as computed together with indicated sound lag.

Test No.	Test	Remarks
22	<i>Cable reel and cable.</i>— a. Check cable for electrical continuity with ohmmeter or buzzer b. Check cable for insulation with megger c. Check length of cables (2). (Each length 450 feet $\pm 1\%$) d. One male and one female plug should be assembled on either end of cable	
23	<i>Electrical connections.</i> All soldered joints should be covered with glyptal lacquer. Terminal markings must be clearly visible and correspond as indicated on drawing No. 800524	
24	<i>Finished inspection.</i>— a. Corrector, serial No. ——— b. Nameplate and parallax graph plate c. Painting d. Luminous paint on ball pointer e. Trouble lamp f. Check all screws and fastenings for proper setting and for burrs, et cetera g. Check for proper drilling and wiring of all horn mountings h. Check fit of helmets in stowage box to master helmet tube i. Examine all graduations and markings on dials j. Check mirror surface and cross lines k. Check fitting of rubber eyepiece l. Check oil cups for hinging and proper closure m. Check horns for riveting and inner lining n. Check platform for creaking, etc. o. Rubber tubing must be flexible	
25	<i>Weight of sound locator proper.</i>— Approximately 500 pounds (excluding cable and cable reels, stowage box and accessories)	

SOUND LOCATOR M2

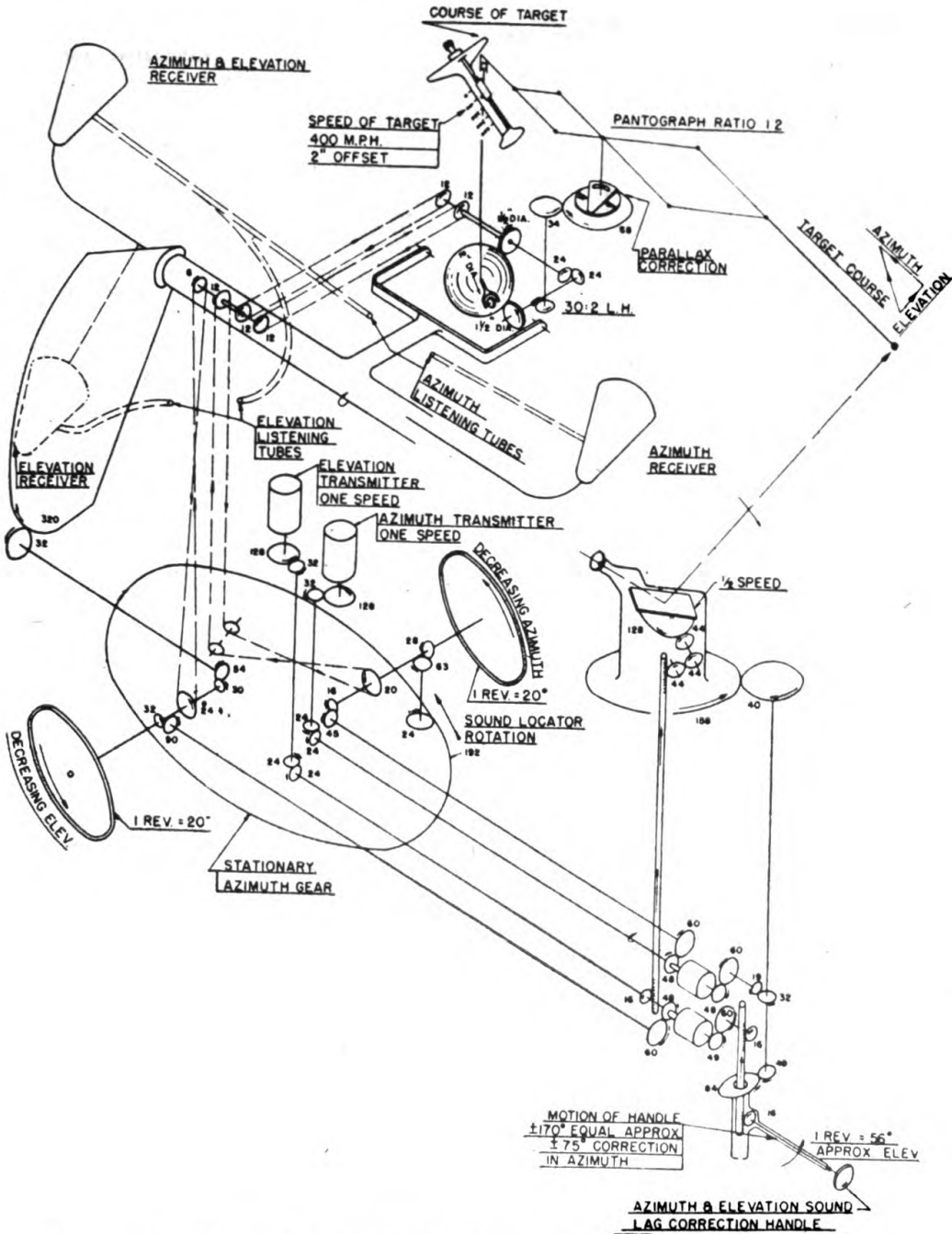


FIGURE 31.—SCHEMATIC GEARING DIAGRAM (Sperry drawing No. 644030-A).

INSTRUCTION GUIDE

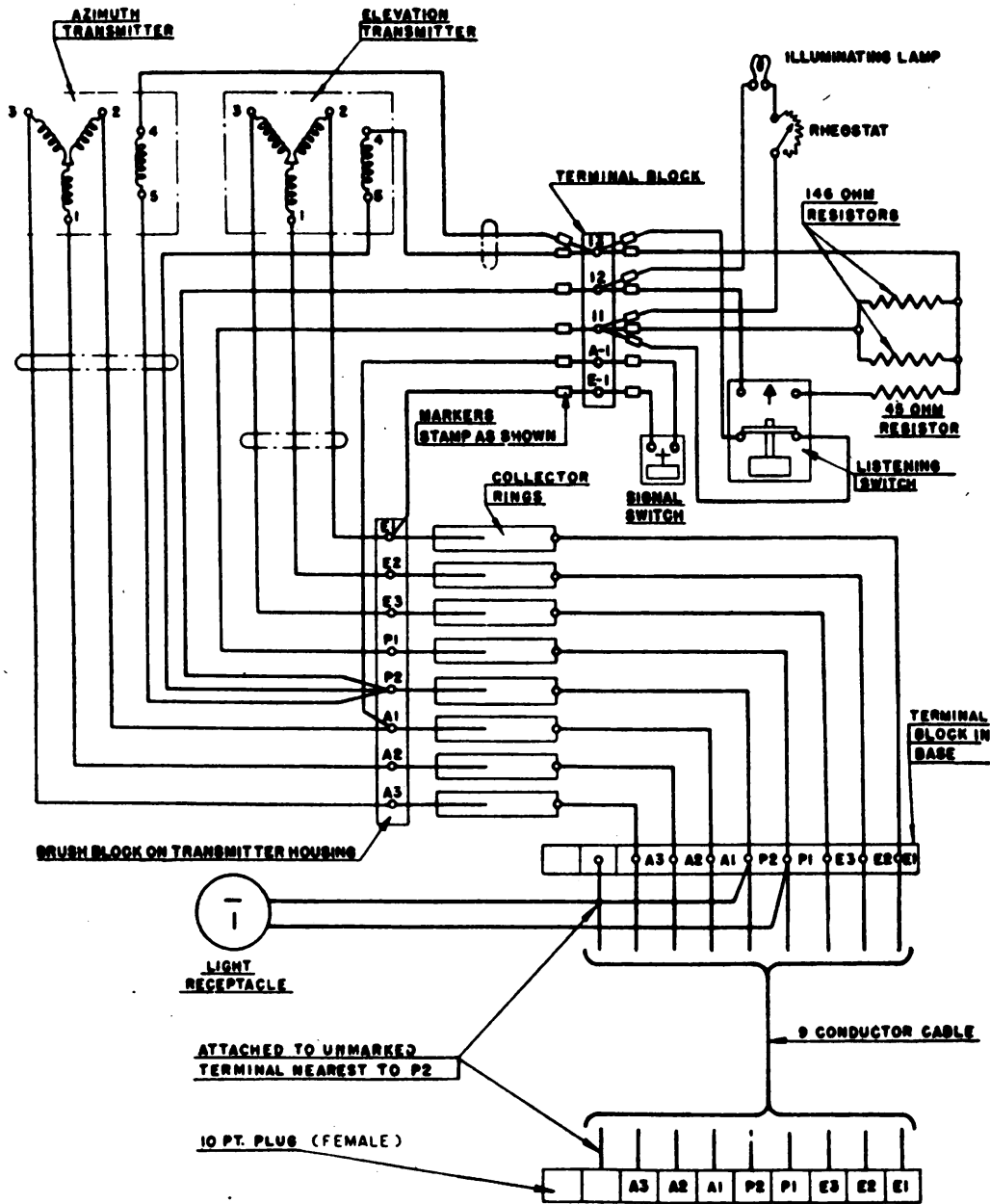


FIGURE 32.—SCHEMATIC WIRING DIAGRAM (Sperry drawing No. 800524-B).

ALPHABETICAL INDEX

A	Page
Accessories.....	40
Acoustical system.....	14, 36
Assembling the sound locator.....	25
Azimuth clutch.....	31
Azimuth handwheel.....	17, 21, 33, 37
Azimuth handwheel clamp knob.....	29
Azimuth scale.....	16, 28
Azimuth train gear.....	16
B	
Ball analyzer.....	7, 46
Base.....	27
Base line.....	11, 27, 52
Binaural sense.....	2, 33, 42
C	
Cable, short extension.....	16, 23, 25
Cables.....	16, 23, 25
Canvas cover.....	34
Caps, metal.....	34
Chain drive.....	17, 39
Characteristics.....	24
Check tests.....	37, 62
Course indicator.....	37
Pantograph and sight mirror.....	37
Parallax pointer.....	37
Choosing operators.....	42
Clamp.....	17, 24
Cleaning.....	34, 35
Column.....	16, 23, 25
Computation of corrections.....	45
Control station.....	31
Corrections, computation of.....	45
Corrections, maximum.....	24
Corrector.....	5, 11, 16
Corrector assembly.....	16, 25
Corrector drive assembly.....	20
Corrector drive mechanism.....	20
Corrector operator.....	32, 42
Corrector operator's handle.....	21, 29, 37
Corrector operator's handle knob.....	21, 37
Course indicator.....	19, 37, 45
Cut-out switch.....	17, 22

INSTRUCTION GUIDE

	Page
D	
Data transmission system.....	9, 17, 21, 22
Data transmitters.....	22
Declutching gear.....	31
Description of mechanism.....	13
Differential.....	21
E	
Ear cups.....	15
Elevation axle.....	17, 25, 37
Elevation friction clamp.....	25
Elevation handwheel.....	17, 21, 33
Elevation rack assembly.....	17
Elevation scale.....	17
Examinations, elimination.....	42
Extension, cable, short.....	16, 23, 25
Eye-guard.....	36
F	
Field training.....	43
G	
Glossary.....	vi
Grease.....	35
H	
Handwheel ratios.....	25
Helmets.....	15, 32
Horns.....	15, 25, 36
Housing (main case).....	16
I	
Inspection report.....	59
J	
Jacks.....	24, 25, 27
L	
Lamp, mirror.....	21
Lamp receptacle (portable).....	16
Light switch.....	21
Limits of operation.....	24
Listeners.....	32, 43
Lubrication.....	38
M	
Main case assembly.....	16
Maintenance.....	34
Metal caps.....	34
Mirror.....	19, 21, 29, 35
Mirror lamp.....	21
Mirror test.....	37

SOUND LOCATOR M2

	N	Page
Noise		1, 2
	O	
Oil		38
Open sight assembly		20
Operation		25
Operators, choosing		42
Orienting and synchronizing in azimuth		27
Orienting and synchronizing in elevation		31
Over-all tests (problems)		38
	P	
Packing		34
Pantograph		26
Pantograph drive assembly		19
Pantograph drive case		19
Pantograph operating stud		19
Pantograph pointer	19, 29, 31, 33, 37, 47	47
Pantograph test		37
Parallax	9, 20, 50	50
Parallax cam		31
Parallax correcting arm		20
Parallax correction		50
Parallax offset		32
Parallax offset mechanism	20, 53	53
Parallax offset scale	19, 29, 37, 51	51
Parallax pointer test		37
Parts list		44
Platform	24, 25	25
Portable lamp receptacle		16
Potentiometer resistors	17, 18	18
Power Plant		29
Power requirements		25
Power terminals		23
Preparing to track		31
Principles of operation		2
Problems	38, 62	62
Push button cut-out switch	17, 22	22
	R	
Receptacle, lamp, portable		16
References		44
Resolving ball	7, 19, 45	45
Resolving ball caster roller		19
Revolving assembly (housing)		17
Rheostat		21
Routine maintenance		34
	S	
Searching mechanism		27
Searchlight	9, 10, 11, 20, 22, 25, 28, 31, 38, 48	48

	Page
Short extension cable.....	16, 23, 25
Signal switch.....	21
Slant range.....	11, 54
Slip ring assembly.....	16, 36
Sound conducting tubing.....	15
Sound lag.....	4, 45, 52
Sound lag angles.....	5
Sound lag correction.....	45, 52
Sound lag correction screw.....	21
Spare parts.....	41
Speed corrector assembly.....	19
Speed corrector scale.....	19, 37
Spirit level.....	18
Spring brush and terminal block assemblies.....	23
Stationary assembly (base).....	16
Storage.....	35, 40
Supporting column.....	17, 23, 25
Switch, cut-out.....	17, 22
Switch, light.....	21
Switch, signal.....	21
Synchronizing.....	27, 29

T

Target air speed.....	31, 38
Testing.....	37, 62
Tools.....	41
Tracking.....	33
Training of personnel.....	41
Transportation.....	25, 34
Transportation bracket.....	25

W

Weights.....	25
Wind error.....	8

